LSCo. Report No. 2123-4.0-4.1

70429

TECHNOLOGY TRANSFER PROGRAM (TTP)

FINAL REPORT

FACILITIES AND INDUSTRIAL ENGINEERING

FACILITIES and INDUSTRIAL ENGINEERING VOLUME 2-APPENDICES

Prepared by:

Levingston Shipbuilding Company
in conjunction with:
IHI Marine Technology Inc.

April 30, 1981

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APPENDIX A

SIGNIFICANT DIFFERENCES

AND

SPECIFIC PRODUCTION IMPROVEMENT AREAS

TASK 4.1

Facilities Capabilities & Capacity

A Significant Differences and A Specific
Production Improvement Areas

Prepared by IMT

1. Preface
2. Significant Difference and Specific Production Improvement Areas
   (1) Mold Loft
   (2) Fabrication and Sub-Assembly
   (3) Assembly
   (4) Erection
   (5) General
3. Summarization

1. Preface

With regards to the difference of the facilities capability and capacity, it is difficult to make simple comparison because of the big differences in basic points between both LSCO and IHI. . .

(1) Producible vessel’s kind and size
(2) Producible throughput
(3) Layout of production flow
(4) Working hour etc.

From above reasoning, in this paper, as a basis of IHI’s production process, we studied to clarify the significant differences in order to obtain high productivity.

2. Significant Difference and Specific Production Improvement Areas

The IHI’s process and main facilities are shown on the attached figures (Fig. 1 - Fig. 7)
According to the figures, the subject comparisons were made here in after.

(1) Mold Loft

As significant difference point, there is the N/C drafter machine. In IHI, the N/C drafter machine is fully utilized in the molld loft process such as making piece drawing and checking N/C tape. In LSCO, there is no N/C drafter machine.
The N/C drafter machine is very useful for not only obtaining high producibility and accuracy butalso useful as a back up system for the N/C burning machine. With regards to the N/C drafter machine, refer to our report concerned with Task 2.2.

(2) Fabrication and Sub-Assembly

The significant differences in this stage are as follows:

(a) Marking equipment of N/C burning machine

LSCO’S machine has the punch marking system and so it needs manual marking to clarify the marked line. This is a big disadvantage and also it is not as good from accurate point of view.
In connection with this, refer to our report concerned with Task 2.2.

(b) Bending Machine

LSCO has the press and roller machine.
Especially, the press machine needs to increase the capability.
This machine has a fixed type ram and no turn press head..
And so, there are many limitation to making various kind of shapes.
Even if the flame bending technique is transfered, as to the shape required big curve value, the press machine is useful for rough bending in advance with the flame bending.
According to the existing machine, the size of plate to be curved has unpractical limitation and so it needs weld joint.

(c) Sub-Assembly

IHI has the conveyor line but in LSCO there are not clarified sub-assembly line.
As to the fixed slab-assembly system, the capacity will be recovered by soft ware from planed maximum throughput point of view.
But, the utilization of semi-auto-weld is big difference between LSCO and IHI. These weld machine with bring big influence to the capacity on the sub-assembly process.

(3) Assembly

The significant differences classified such as panel, curved .and three dimensions units are as follows:

(a) Panel Unit Assembly

Panel assembly line through from the lay out of plate to the welding between the panel and stiffeners is being built in LSCO.
After finish the said panel line in LSCO, there are not so big difference between LSCO and IHI.

(c) Scaffold .

The scaffolds on outside of ship and inside of cargo holds are big difference between LSCO and IHI.
In IHI, the movable scaffold units are used effectively on.said area instead of conventional scaffold.

(5) General

The specifi significant difference in each process is as mentioned above.
In addition, as general item through production, there are the following difference points.

(a) Utilization of Jigs

In IHI, at every production process through from fabrication to erection, the effective jigs to be meet with production method are being widely utilized.
These jigs will influence the productivity improvement in addition to the vital facilities.
The utilized ratio of these jigs is big difference between LSCO and IHI.

(b) Utilization of Auto or Semi-Auto Welding Machine

As noted above, the utilized ratio of said weld machine is big difference.
Especially, the gravity weld machine is most useful and so an increase in utilization ratio will bring much productivity.

3. Summarization

From the facilities capability and capacity point of view, the specific production improvement areas are reported as noted above.
Some of the items are already being improved with LSCO.
In the improvement of these kind areas, it is important to achieve with consideration of software such as ship’s design, production method and so on.
As the next step, we would like to assist LSCO to improve the said specific production improvement areas.

(b) Curved Unit Assembly

There are big difference between LSCO and IHI.
In LSCO, the plate jig has been used only for a part of curved units and almost all of the curved units have been assembled by means of the frames as the guidance of plate assembly.
From such a reason, in LSCO, there are no jigs product oriented.

(c) Three Dimensions Unit Assembly

There are also big difference between LSCO and IHI.
In LSCO, there are no consideration to make positioning in order to obtain more efficiency of weld.
In IHI, the cranes concerned with the assembly have auxiliary lifting equipment to be used for turning over, positioning and so on.
The productivity of assembly will be influenced by the said kind of the facilities.

(4) Erection

The significant differences except launch method are as follows:

(a) Cranes Capacity

There is a big difference in capacity, but in case of considering the LSCO'S building speed and necessary . productivity compared with assembly, LSCO'S crane capacity is not so small we think.
Of course, it is better to furnish the big crane for making big units but LSCO'S existing capacity not bringing big trouble for building the bulkers.

(b) Weld Machine

The utilization of auto or semi-auto-weld machine is big difference between LSCO and IHI.
As to details, refer to the report "FPC-156Weld Method Improvements".
The utilization of these weld machine will bring big influence to the productivity on the erection process.

'''''. 1

FLOW CHART OF MOLD LOFTING

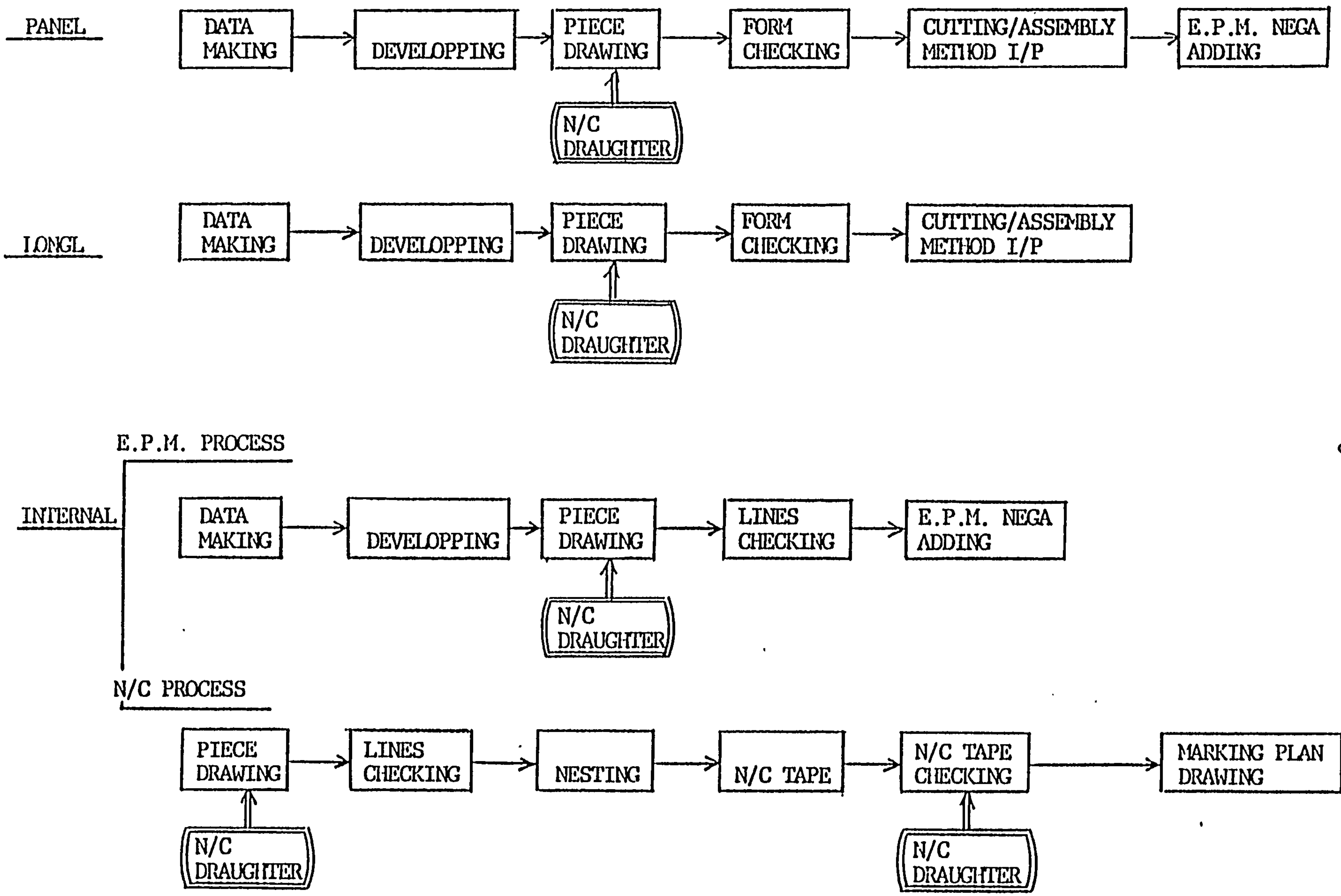


FIG. 2

FLOW CHART OF FABRICATION (1/2)

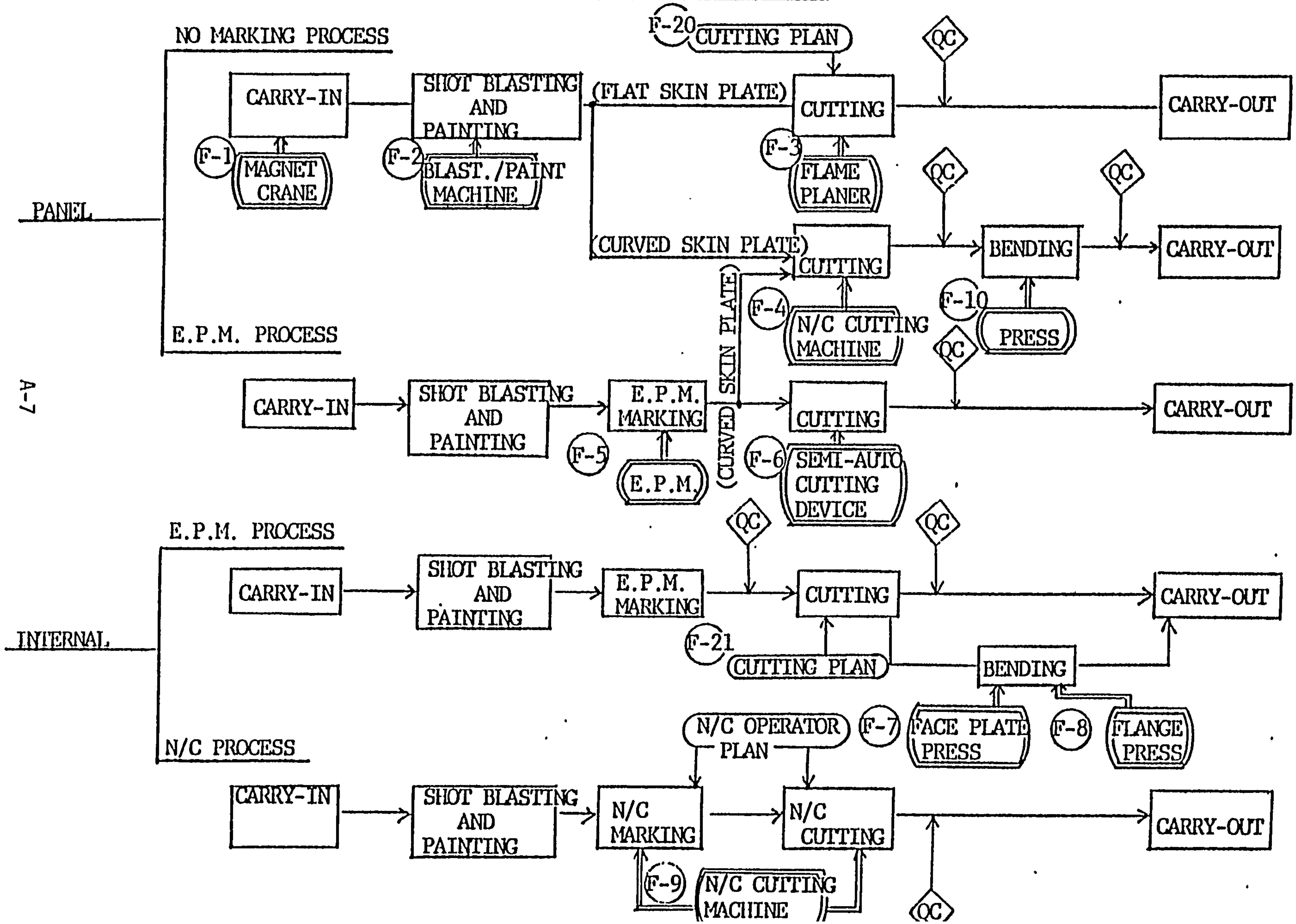


FIG. 4

FLOW CHART OF SUBASSEMBLY

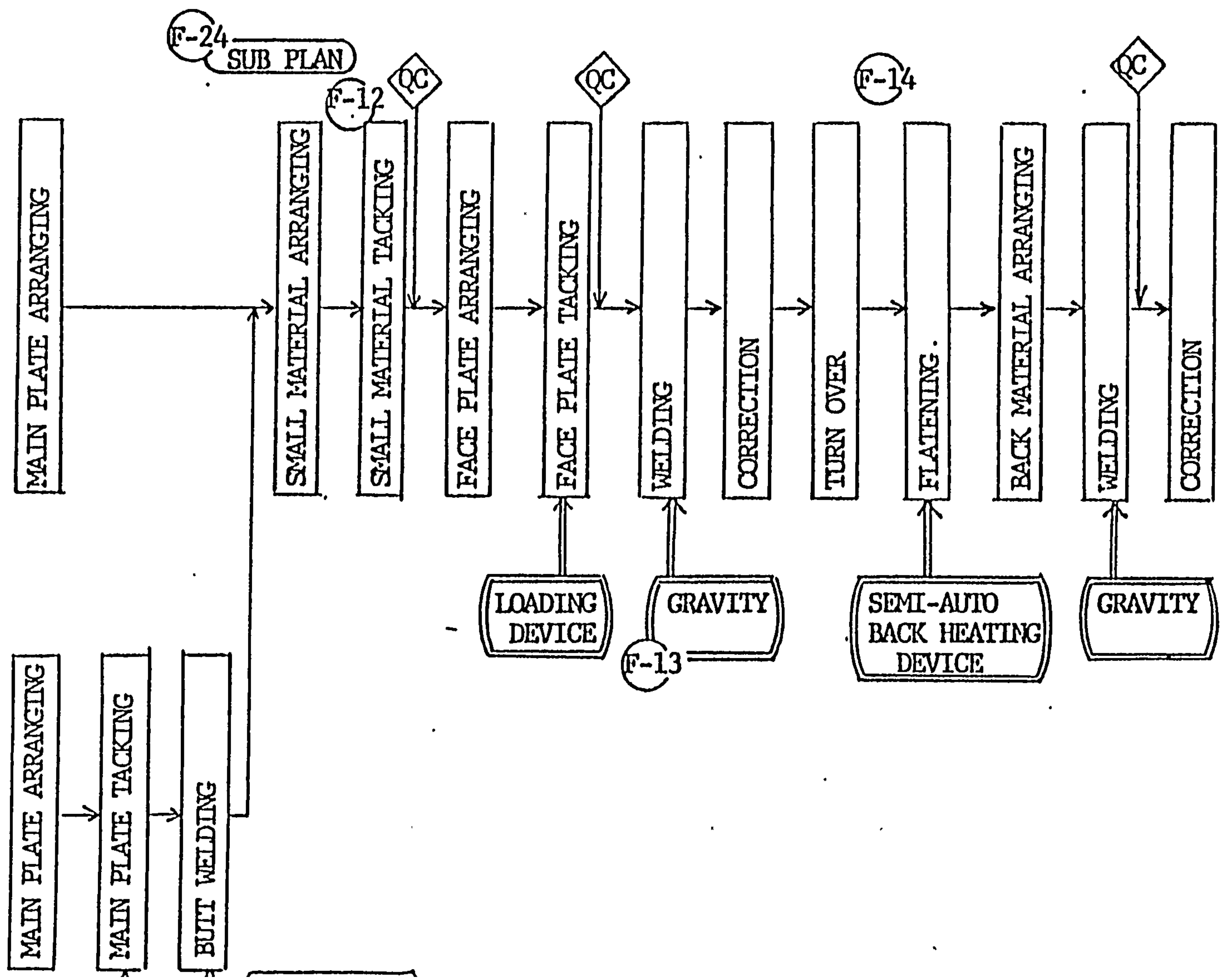
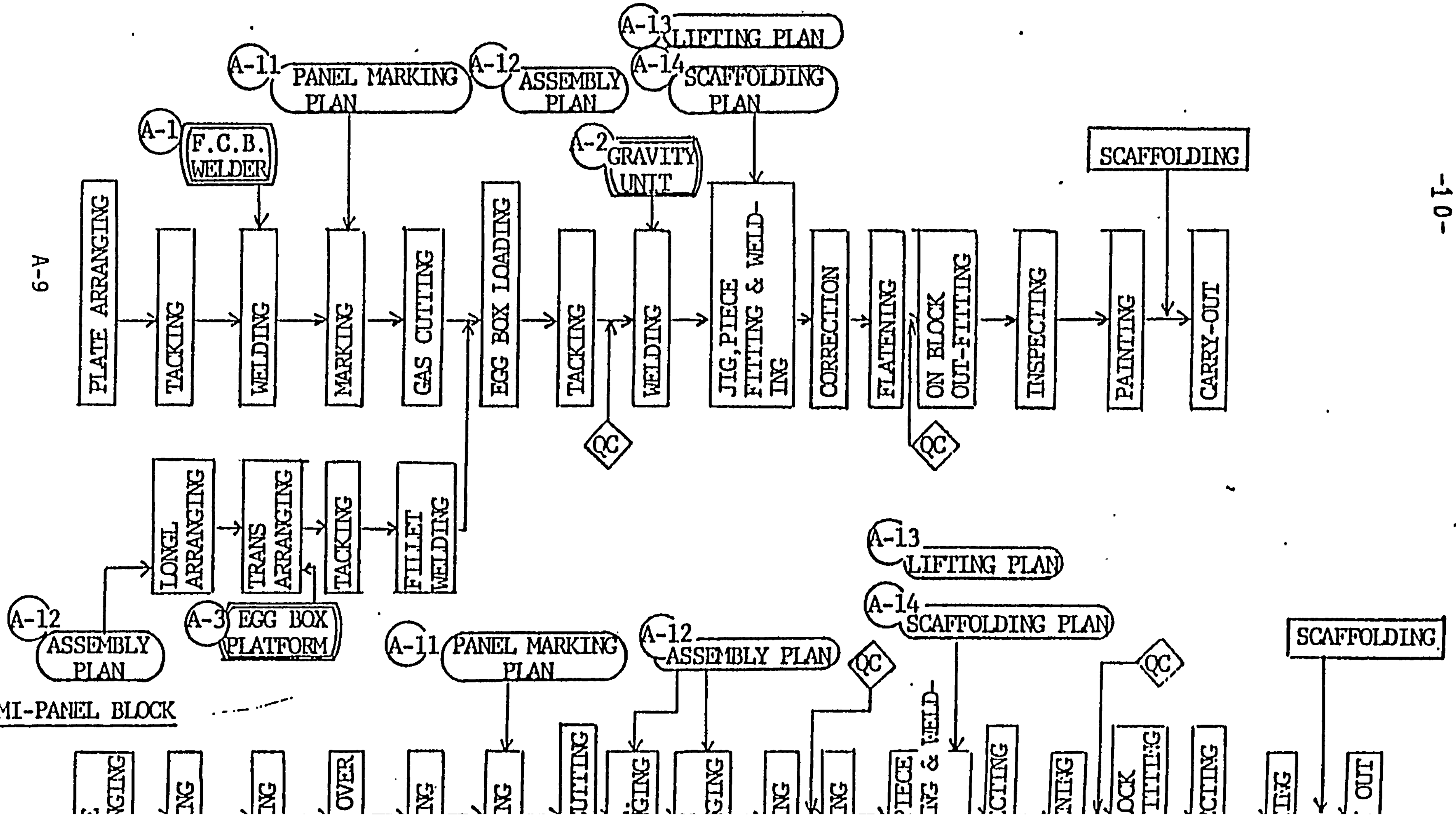


FIG. 5

FLOW CHART OF FLAT PANEL ASSEMBLY

1. PANEL BLOCK

EGG BOX METHOD



2. SEMI-PANEL BLOCK

FIG. 6

FLOW CHART OF CURVED PANEL ASSEMBLY

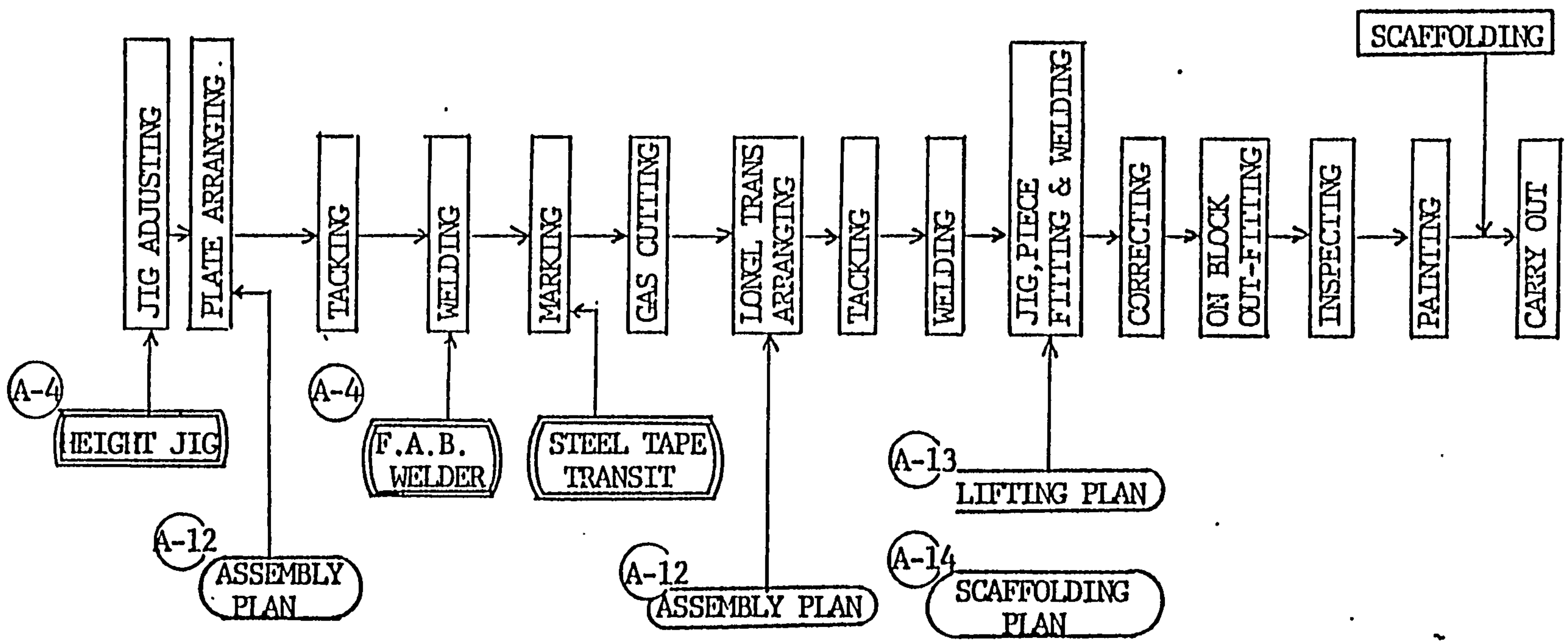
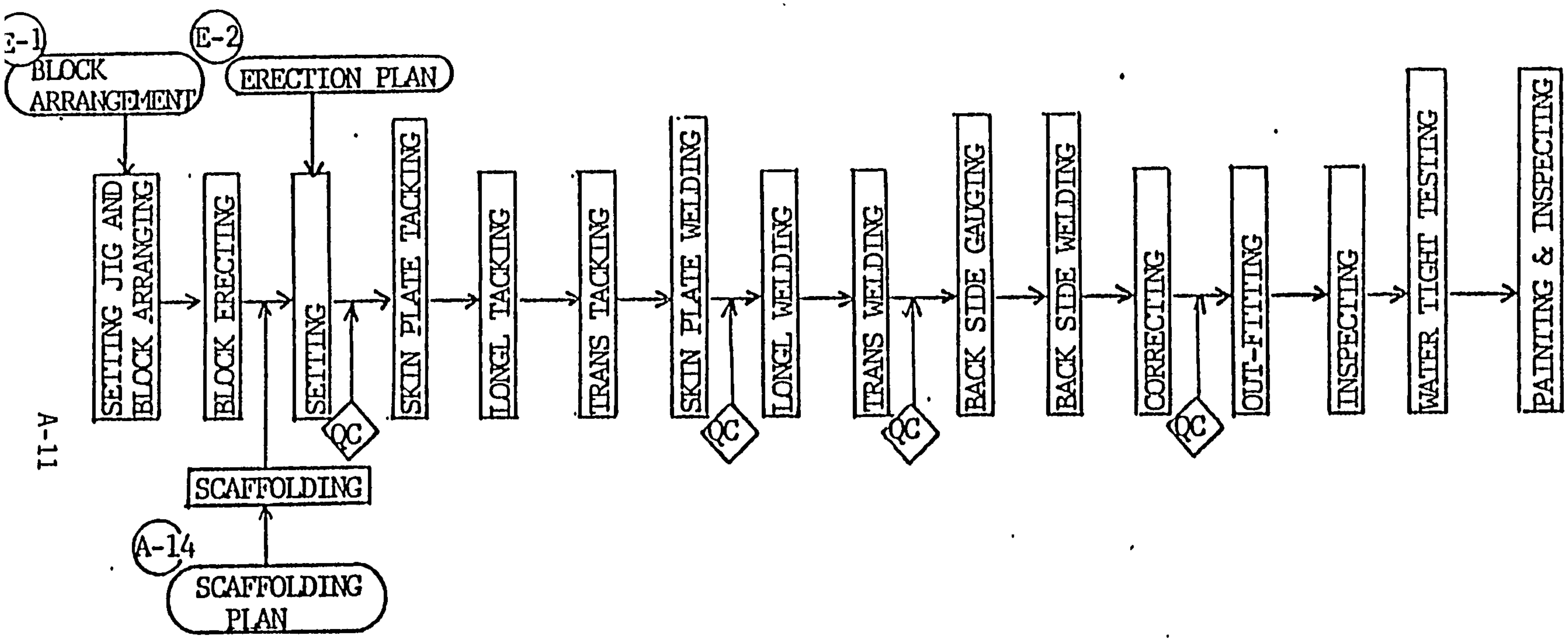


FIG. 7

FLOW CHART OF ERECTION



APPENDIX B

GENERAL VIEW OF LEVINGSTON

IIII MARINE TECHNOLOGY, INC. 4.2-6-4

Ref. No. HP-104

REC'D IND. ENG.

JUN 20 1979

MEMORANDUM

June 20, 1979

TO: Clyde LaRue

FROM : T. Yamamoto

SUBJECT : General View of LSCO

Recently Yotaro Kanoh, Director of IHI and a member of the Board, visited this shipyard. On this occasion, the following points were suggested that perhaps would improve the operation of this shipyard.

1. Grinding Job for Internal Structure After N/C Cutting

It would be possible to avoid grinding if the cutting tip was cleaned periodically, height and speed properly adjusted, and if N/C programs were modified for the cutting procedure.

Our engineers will investigate further for a solution to the problem.

2. Untidy Working Area

At this time, general shipyard housekeeping is not in operation properly. In maintaining clean working areas, the following profits will be realized:

(a) Safe working places with proper passage
(b) Material loss will be avoided
(c) High quality will be maintained

This will automatically increase productivity.

Recently at LSCO, working areas were designated as gates and foremen were assigned to these gates, respectively.

In this connection, the assigned foreman in his assigned area takes responsibility of production, as well as housekeeping. Therefore, the labor department's responsibility is to keep public space (such as the roads) clean and to keep scrap and rubbish cans cleared as a public service.

3. Material Storage Area and Material Pallet

There are many materials in this yard which are difficult to distinguish as a necessary or unnecessary material. It will be economically feasible to take the following action on the matters listed below:

(a) Keep present unnecessary materials in specific areas in order to make pallets, jigs or scrap.
(b) Establish the proper material storage area near working area, respectively.
(c) Store necessary material with pallet into adequate storage area.

4. Movable Shelter for Slab Areas

The majority of working areas in this shipyard are not covered from heavy rainfall and sunshine. More movable shelters are essential for protection. Its cost will be compensated by increased productivity.

5. Erection Working Procedure

Before finishing welding of the joints of the double-bottom side unit, the stool unit was erected. This is not the preferable method since it is necessary to weld at least the tank top joint before stool erection.

In the erection stage, it is especially important to finish each unit in order to avoid simultaneous work with many workers in the same area.

The above items are only a few points suggested that could improve the operation of this shipyard. We feel that it would be beneficial to LSCo if your personnel, together with our engineers, formed a committee in order to study operations and procedures of LSCo and find agreeable, effective solutions and implement them.

Due to our many years of shipbuilding experience, we can say that a high level of safety precautions and the avoidance of unnecessary working in production is imperative to a high quality of work and the achievement of high productivity.

We would greatly appreciate your prompt response in the above matters.

TY/llt

CC: Ed Paden
Tim Colton
Marvin Russell
Woody Gaines
Russ Teel
Ron McKenney

APPENDIX C

METHOD IMPROVEMENT: WELDING

2. APPLICATION STANDARD IN LSCO FOR WELDING METHOD BASED ON IHI

		Ref. No.
A.	Two-Sided Submerged Arc Welding	HP-029
B.	Gravity Welding	HP-032
C.	Vertical Down Welding	HP-033
D.	Welding Procedure of 50 kg/mm^2 (71000 PSI) High-Strength Steel	HP-086

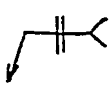
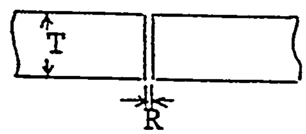
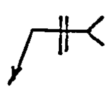
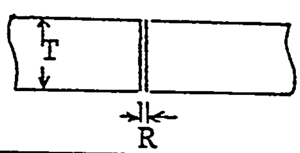
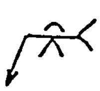
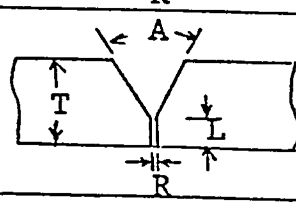
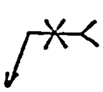
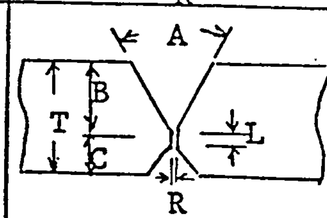
Ref. No. HP-029
February 23, 1979

TWO-SIDED SUBMERGED ARC WELDING

1. OUTLINE

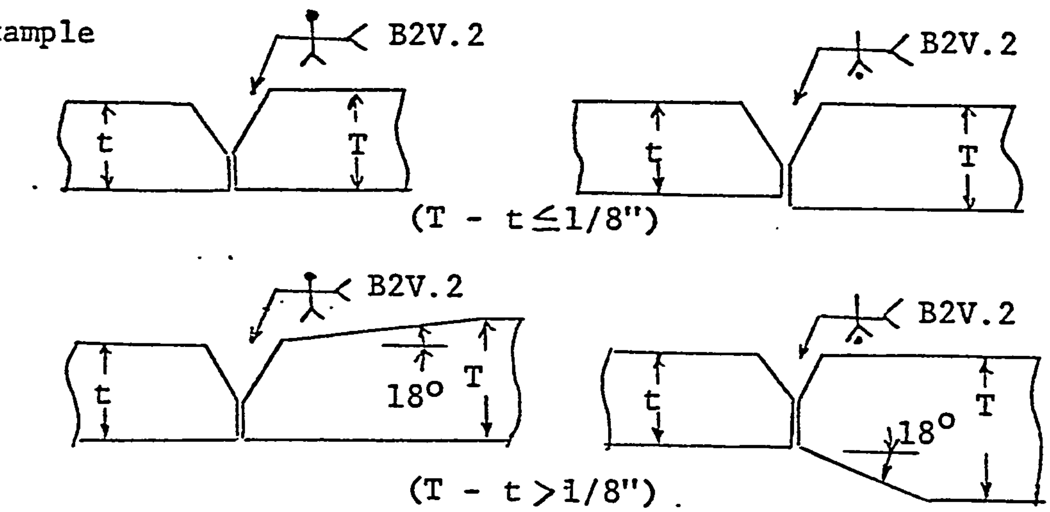
In this method, backing side (side 1) is first after the turning-over of the plate finishing side (side 2). This is the most common submerged arc welding method. Applicable parts are flatt butt joints of Assembly stage and Sub-Assembly stage.

2. APPLICABLE CONDITION

WELDING SYMBOL	EDGE PREPARATION	STANDARD RANGE OF THICKNESS	ALLOWABLE LIMITATION
 B2S.3		inch 1/4 ≤ T ≤ 7/16 R = 0	inch R ≤ 1/16
 B2S.5		7/16 ≤ T ≤ 5/8 R = 0	R ≤ 1/16
 B2V.2		1/2 ≤ T ≤ 1 R = 0 L = 3/16 A = 45°	R ≤ 1/16 1/8 ≤ L ≤ 1/4
 B2V.5		1 1/16 ≤ T ≤ 1 1/2 R = 0 L = 1/8 A = 60° B=2/3T C=1/3T	R ≤ 1/16 1/16 ≤ L ≤ 3/16

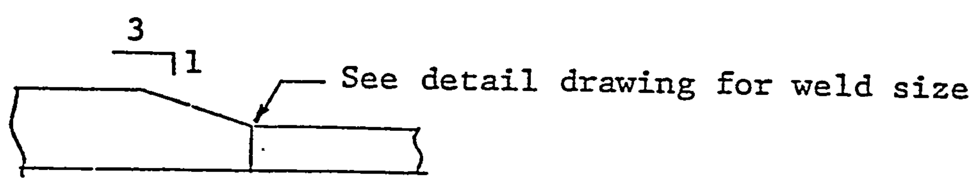
3. DIFFERENCE OF PLATE THICKNESS (IHI's PROPOSAL)

Example



LSCO's Typical Chamfer at Plate Seam
Std. No. SD-26

18° ≑ 3 / 1



NOTE: Chamfers are used when there is a difference of 3/16" or more in the two plates being joined.

4. WELDING EQUIPMENT

Welding Power Sources:	Lincoln - SA800 Type 460V (3 phase, 60 Hertz) Output: DC 800A
Welding Machine :	Electrode polarity - positive One electrode. Flux self vacuum. Without truck.

5. WELDING MATERIALS

	FILLER WIRE	FLUX	T	GRADE
ORDINARY STRENGTH STEEL	(a) L - 61	# 780	≤1"	ALL
	(b) L - 60	# 780	≤5/8"	A only
	(c) L - 61	# 860	≤1 1/2"	ALL
HIGHER STRENGTH STEEL	(a) L - 61	# 780	<1"	All H.T. except EH grades
	(b) L - 61	# 860	<3"	ALL

6. TACK WELDING

Electrode — Ordinary Strength Steel: E6011, E7018
Higher Strength Steel : E7018

Tack Welding Length: Approximately 2" - (sufficient to hol
Tack Welding Pitch : ab 12"

7. WELDING PREPARATIONS

A. Weld area shall be free of all oil or grease and excessive rus or scale. Cleaning may be made by brushing, blasting, etc., or any other method of assure compliance with the above.

(1) Moisture shall be removed by pre-heating when necessary.

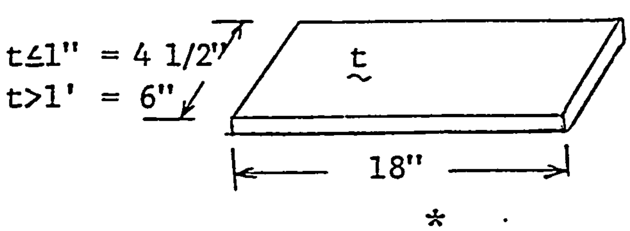
B. Flux Constrol: When using a new bag, with a 12-hour period, allow to use without drying. But if it is more than above, theflux should be dried at at temperature of 390°F (250°C) for one hour before use.

7. WELDING PREPARATIONS (cont.)

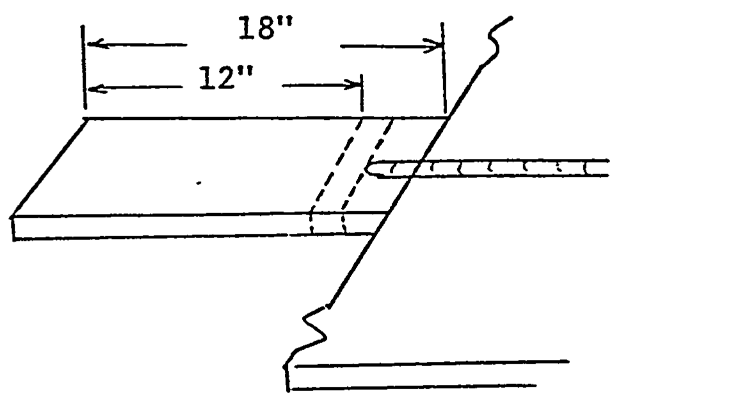
C. RUN-OFF TAB

Base Plate and Tab Plate

BASE THICKNESS (inch)		1/4- 3/8	7/16-9/16	5/8-3/4	13/16- 1 1/16	1 1/8 - 1 1/4	1 5/16 - 1 7/16
TAB	THICKNESS	5/16"	1/2"	11/16"	1"	1 3/16"	1 3/8"
	SIZE	4 1/2" x 18"				6" x 18"	



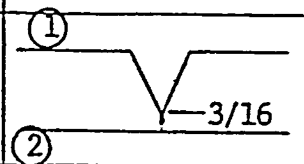
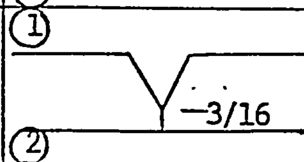
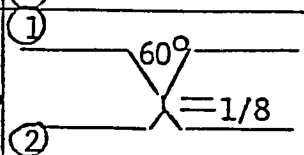
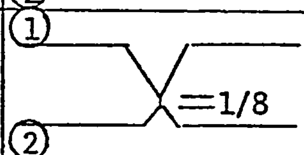
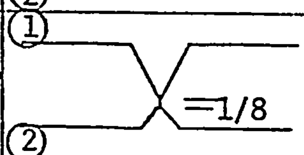
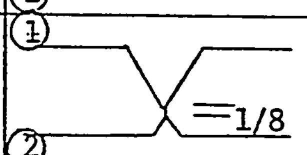
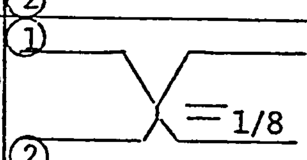
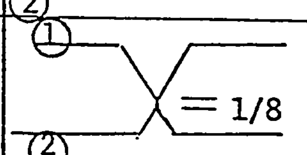
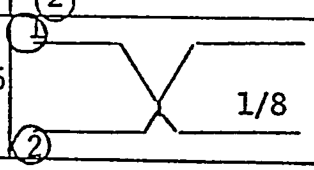
* To be used up to 12" by recut.



8. STANDARD WELDING CONDITION

T inch (mm)	EDGE PREPARATION	BACKING PASS A	BACKING PASS V	BACKING PASS IPM	FINISH PASS A	FINISH PASS V	FINISH PASS IPM	Elect.	Dia.	Flux
1/4 (6.4)	① ②	① 475	29	40	② 575	32	40	L-61	5/32	780
5/16 (8)	① ②	① 500	30	38	② 575	32	34	"	5/32	780
3/8 (9.5)	① ②	600	32	38	750	33	35	"	5/32	780
7/16 (11.1)	① ②	650	33	38	800	34	34	"	3/16	780
1/2 (12.7)	① ②	750	34	33	850	36	33	"	3/16	780
9/16 (14)	① ②	750	34	30	850	36	32	"	3/16	780
5/8 (16)	① ②	750	35	36	850	36	24	"	3/16	780
11/16 (17.5)	① 45° 3/16 ②	① 525/675	29/32	14/20	② 650/700	32/34	25/30	"	5/32	860
* 3/4 (19)	① 45° 3/16 ②	① 525/675	29/32	14/20	② 650/700	32/34	25/30	"	5/32	860
13/16 (20.6)	① 45° 3/16 ②	525/675	29/32	14/20	650/700	32/34	25/30	"	5/32	860
7/8 (22.2)	① 45° 3/16 ②	525/675	29/32	14/20	650/700	32/34	25/30	"	5/32	860

* Root Pass by some other process where necessary. Y-Groove is Multiple Pass.

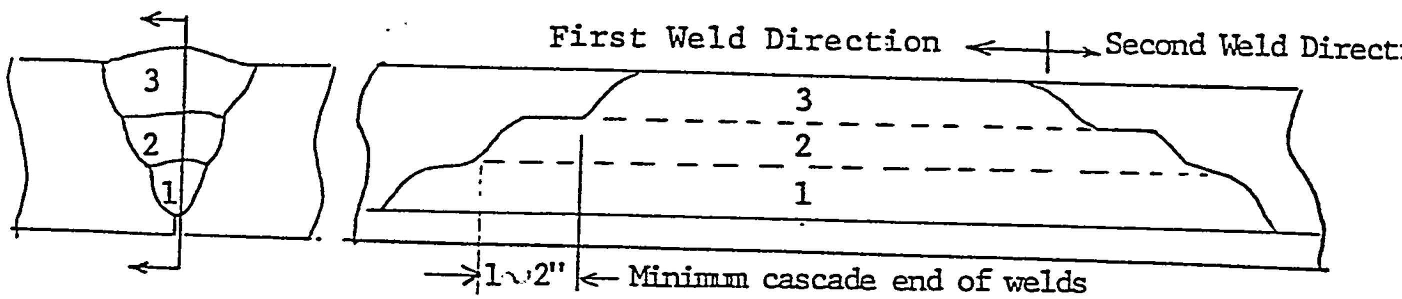
T inch	EDGE PREPARATION	BACKING PASS A	V	in/min.	FINISHING PASS A	V	in/min	Elect.	Dia.	Flux
* 15/16		① 525/675	29/31	14/20	② 650/700	32/34	25/30	L-61	5/32	860
* 1		① 525/675	29/31	14/20	② 650/700	32/34	25/30	"	"	"
* 1 1/16		525/675	29/31	14/20	650/700	32/34	25/30	"	"	"
* 1 1/8		525/675	29/31	14/20	650/700	32/34	25/30	"	"	"
* 1 3/16		525/675	29/31	14/20	650/700	32/34	25/30	"	"	"
* 1 1/4		525/675	29/31	14/20	650/700	32/34	25/30	"	"	"
* 1 5/16		525/675	29/31	14/20	650/700	32/34	25/30	"	"	"
* 1 3/8		525/675	29/31	14/20	650/700	32/34	25/30	"	"	"
* 1 7/16		525/675	29/31	14/20	650/700	32/34	25/30	"	"	"

* Root Pass by some other process or at low enough amperage to prevent burn-through.

9. SOME COMMON WELDING ERRORS AND SUGGESTED CORRECTIONS

A. Bead Joint

Weld configuration desirable where multi-pass welds are made starting at a given point and welding in each direction. Typical example is skip welding and plate joint intersections.

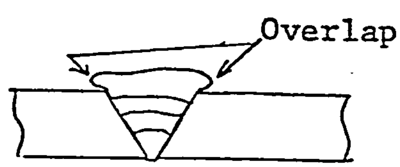


Where cascade method has not been used and each pass is equal in length, starting and stopping at the same point of the pass underneath it, the ends may be prepared by beveling the total bead thickness to approximately 30° by carbon arc gouge, chipping or grinding. This will provide an end condition similar to that created by the cascade method.

B. Undercut

Depth of Cut: up to 1/64" (0.5mm)

C. Overlap



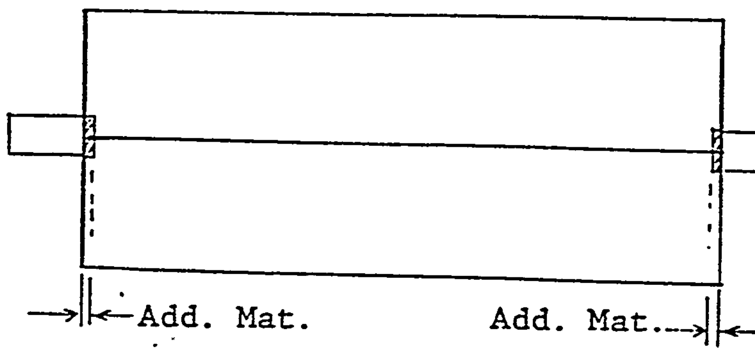
Correct by <u>removing</u> excess weld metal. Toe bead may be used where complete penetration can be accomplished.

D. Weld Reinforcement

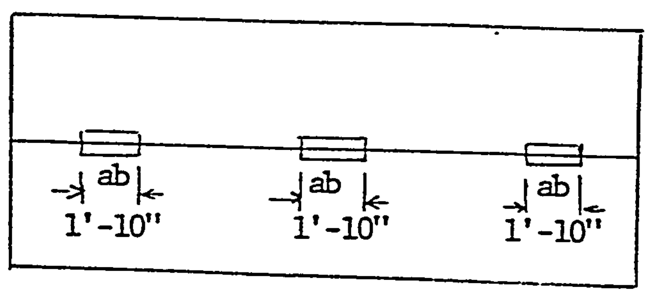
Weld reinforcement should be approximately 1/16" high and shall not exceed 3/16" in height. There shall be a gradual transition to the plane of the base metal surface. Excess reinforcement shall be removed.

10. INSPECTION

(1) Macro-Test



(2) U.T. Test



EACH SIDE SUBMERGED ARC WELDING (SINGLE) IHI CONDITIONS

PLATE THICKNESS INCH	mm	EDGE PREPARATION	BACKING PASS A	V	IPM (CPM)	FINISHING PASS A	V	IPM (CPM)
1/4	6		530	34	19.7 (50)	750	34	25.6 (65)
9/32	7		580	34	19.7 (50)	800	34	25.6 (65)
5/16	8		620	34	19.7 (50)	850	34	24.8 (63)
11/32 3/8	9		650	34	19.7 (50)	880	34	24.8 (63)
13/32	10		680	34	19.7 (50)	900	35	23.6 (60)
7/16	11		700	34	20.5 (52)	920	35	22.8 (58)
15/32	12		730	34	21 (53)	950	35	21.7 (55)

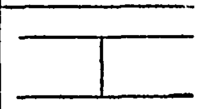
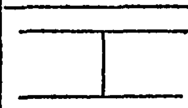
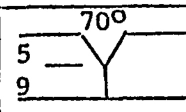
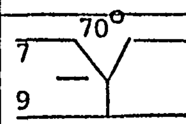
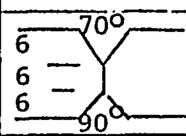
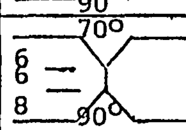
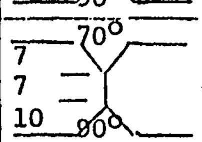
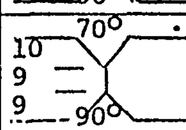
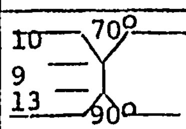
ROD US-43 . 4.8 DIA. FLUX PFH-45

PLATE THICKNESS INCH	mm	EDGE PREPARATION	BACKING PASS A	V	IPM (CPM)	FINISHING PASS A	V	IPM (CPM)
13/32	10		720	33	21.7 (55)	900	38	23.6 (60)
7/16	11		760	33	21.7 (55)	920	38	22.8 (58)
15/32	12		800	33	21.7 (55)	940	38	22 (56)
1/2	13		830	33	21.7 (55)	950	38	21.3 (54)
17/32 9/16	14	70° 5 9	800	32	17.7 (45)	930	38	19.7 (50)
19/32	15	70° 6 9	830	32	17 (43)	950	39	18.5 (47)
5/8	16	70° 7 9	870	32	15.7 (40)	980	39	17.7 (45)
21/32	17	70° 8 9	900	32	14.6 (37)	1020	39	17 (43)
23/32	18	70° 6 6 6 90°	820	32	14.6 (37)	1100	36	14.2 (36)
3/4	19	6 70° 6 7 90°	820	32	14.6 (37)	1100	36	13.8 (35)

ROD US-43 6.4 DIA. FLUX PFH-45 B. PASS
KW-43 KB-14 F. PASS

DITIONS

SINGLE ⟶ ⟵ TANDEM

BACKING PASS A	BACKING PASS V	BACKING PASS IPM (CPM)	FINISHING PASS A	FINISHING PASS V	FINISHING PASS IPM (CPM)	PLATE THICKNESS INCH	PLATE THICKNESS M/M	EDGE PREPARATION		BACKING PASS A	BACKING PASS V	BACKING PASS IPM (CPM)	FINISHING PASS A	FINISHING PASS V	FINISHING PASS IPM (CPM)
830	32	13.8	1100	36	12.6	13/32 7/16	10		L	600	32	31.5	750	32	31.5
									T	600	36	(80)	750	38	(80)
880	32	13	1130	37	11.8	15/32	12		L	650	32	31.5	800	33	29.5
									T	650	36	(80)	800	38	(75)
950	32	12.6	1200	37	10.2	17/32 9/16	14	 70° 5 9	L	750	32	27.6	900	34	29.5
									T	750	36	(70)	900	38	(75)
960	32	11.8	1200	37	10.2	5/8	16	 70° 7 9	L	850	32	25.6	1000	35	28.7
									T	850	36	(65)	1000	38	(73)
1050	33	10.6	1300	38	9.8	23/32	18	 70° 6 6 6 90°	L	700	32	27.6	1000	33	27.6
									T	700	36	(70)	1000	38	(70)
1100	34	10.6	1400	38	9	25/32	20	 70° 6 6 8 90°	L	720	32	26.8	1050	33	25.6
									T	720	36	(68)	1050	38	(65)
1150	34	9	1400	38	7.9	15/16	24	 70° 7 7 10 90°	L	800	32	24.4	1100	34	20.9
									T	800	36	(62)	1100	38	(53)
						1 3/32	28	 70° 10 9 9 90°	L	900	32	19.7	1150	32	18.9
									T	900	36	(50)	1150	38	(48)
						1 1/4	32	 70° 10 9 13 90°	L	950	32	18.9	1200	32	15
									T	950	36	(48)	1200	40	(38)

a. FLUX PFH-45 B. PASS
KB-14 F.PASS

ROD US-43 L:48 DIA. FLUX PFH-45 B. PASS
KW-43 T:6.4 DIS. KB-14 F. PASS

Ref. No. HP-032
February 28, 1979

GRAVITY WELDING

1. GENERAL

Gravity welding is a semi-automatic welding method which utilizes natural gravity in the welding process. Primarily applicable to horizontal fillet welds in assembly or sub-assembly stages.

2. EQUIPMENT

The gravity welding unit is a simple structure designed to hold the electrode at the proper drag angle and proper electrode angle-to-joint posture. The equipment is designed so that the weld bead size and quality is controlled by:

(a) Electrode diameter
(b) Drag angle and electrode angle-to-joint
(c) Amperage

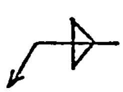
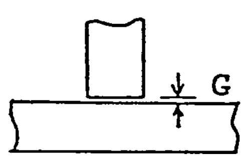
All these items can be adjusted as necessary.

The units are equipped with a switch which is only to be used to initiate the arc and is to be disengaged when the arc is automatically extinguished. The electrode is placed in the electrode holder and the tip of the electrode is placed in the anpropriate starting position. When the switch is activated the arc is started and continues to weld until the electrode is consumed and the holder automatically extinguishes the arc.

3. ELECTRODE

Gravity feed electrodes are 700mm (27 1/2") long and will be available in sizes of 3/16", 7/32" and 1/4". The tip of the electrode is provided with a special material to initiate an easy start. The electrode is designed to perform best on an AC current.

4. APPLICABLE CONDITION

WELDING SYMBOL	EDGE PREPARATION	STANDARD GAP	ALLOWABLE LIMITATION
 The same as manual welding		G = 0	G ≤ 3/32" (2.3mm) *

* Weld leg length shall be increased by gap.

5. WELDING EQUIPMENT

AC Power sources - 400 Amps or over, 60 Hertz, Lincoln Miller, Airco.

Gravity Machine: Type - Fematic Slide bar length 39½" Made by ESAB 10 lb. weight

6. WELDING MATERIALS

	ELECTRODES	
	AWS	ESAB
ORDINARY STRENGTH STEEL	E 6027	5^{ϕ}x 700ℓ 5.6^{ϕ}x 700ℓ 6^{ϕ}x 700ℓ
7000 PSI HIGHER STRENGTH STEEL		

7. TACK WELDING

Electrode Ordinary strength steel: E 6011, E 7018
Higher strength steel : E 7018

Tack Welding Length: Standard 2" In case of H.T.≥ 2"
Tack Welding Pitch : ab 12∼16"

8. WELDING PREPARATIONS

(1) Weld area shall be free of all oil or grease and excessive rust or scale. Cleaning may be accomplished by any suitable means including grinding or brushing, moisture shall be removed by heatin

(2) Electrodes Control

For mild steel: If electrodes have absorbed moisture, dry them at 160°∼210°F (70°∼100°C) for one hour. To prevent moisture, it is recommended that warmer facilities at 120°∼210°F (50°∼100°C) be used.

For higher steel: The electrode should be dried at a temperature of 580°∼660°F (300°∼350°C) for one hour before use.

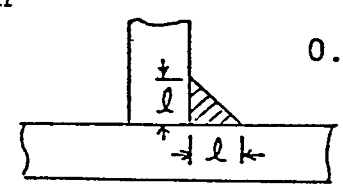
9. STANDARD WELDING CONDICTION

LEG LENGTH	ELECTRODE DIA	CURRENT	SPEED RATIO *
3/16 inch (4.8mm)	5mm (3/16")	250 (A)	1.3
7/32 (5.5mm)	5.6mm (7/32")	285	1.8
1/4 (6.4mm)	6mm (1/4")	350	1.8
7/32 (7.1mm)			
5/16 (7.9mm)			
11/32 (8.7mm)			

$$* \text{ SPEED RATIO} = \frac{\text{Bead length (inch)}}{\text{Melting length (inch)}}$$

10. SOME WELDING ERRORS AND CORRECTIONS

A. Leg length



Allowable limitations

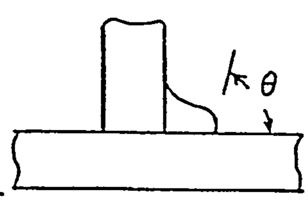
$0.9L \geq \ell$ L = Regulation length

Less than 0.9L to be corrected by welding.

B. Bead Undercut

Depth of cut: up to 1/64" (0.5mm)

C. Bead Overlap



$\theta < 90°$: To be chipped by grinding or to be corrected by welding

D. Weld Crater

Not allowed: To be ground or chipped and corrected by welding

11. INSPECTION

Bead appearance inspection. (Items 10-A~D) Check by gauge and visual.

IHI MARINE TECHNOLOGY, INC.

REFERENCE DATA FOR GRAVITY ARC WELDING

*1 SPEED RATIO	ROD LENGTH inch	*2 BEAD LENGTH inch	LEG LENGTH	ROD DIA. (mm)	CURRENT A	MELTING RATE I/min	*3 WELDING SPEED I/min	ARC TIME Min/Rod	B Min/M	ROD SPENDING lbs/M	*4 POSSIBLE MACHINE No./Man.	*5 ROD JOINTS No./km	*6 WORK TIMES $Hr/5^{W}/km$
1.3	21.6" (550mm)	25.2" (640mm)	3/16	4.5	195	9.1	11.8	2.1	3.3	0.50	4	1563	7.0
			7/32	5	225	8.7	11.3	2.2	3.5	0.59			7.3
			1/4	6	280	8.1	10.5	2.4	3.8	0.77			7.8
			9/32	6.4	305	8.0	10.4	2.4	3.8	0.87			7.9
			5/16	7	325	7.8	10.3	2.5	3.9	1.0			8
			11/32	8	370	7.3	9.5	2.7	4.2	1.23			8.7
	27.6" (700mm)	32.7" (830mm)	3/16	4.5	190	9.2	12.0	2.7	3.3	0.50	4	1205	6.9
			7/32	5	220	8.2	10.6	3.1	3.7	0.57	5		6.2
			1/4	6	280	8.1	10.6	3.1	3.7	0.75			6.2
			9/32	6.4	300	8.0	10.4	3.1	3.8	0.84			6.3
			5/16	7.5	350	7.5	9.7	3.4	4.1	1.06			6.8
			11/32	8	380	7.3	9.5	3.4	4.1	1.22			6.9
	35.4" (900) mm	42.9" (1090) mm	1/4	6	280	8.3	10.8	4.0	3.2	0.74	6	917	5.1
			9/32	6.4	300	8.0	10.7	4.0	3.4	0.84			5.2
			5/16	7.5	350	7.6	9.9	4.3	3.5	1.05	7		4.8
			11/32	8	380	7.5	9.8	4.4	3.6	1.19			4.8
1.5	27.6" (700mm)	37.8" (960mm)	7/32	5.5	240	8.1	12.2	3.1	3.2	0.55	5	1040	5.4
			1/4	6.4	290	7.7	11.6	3.3	3.4	0.73			5.7
			9/32	7	320	7.5	11.2	3.4	3.5	0.84			5.9
			5/16	8	370	7.3	11.0	3.5	3.6	1.04	6		5.0
	35.4" (900) mm	49.6" (1260) mm	7/32	5.5	240	8.1	12.2	4.1	3.2	0.54		795	4.5
			1/4	6.4	290	7.7	11.6	4.3	3.4	0.72	7		4.1
			9/32	7	320	7.5	11.2	4.5	3.5	0.82			4.2
			5/16	8	370	7.3	11.0	4.5	3.6	1.04			4.3

*1 SPEED RATIO	ROD LENGTH inch	*2 BEAD LENGTH inch	LEG LENGTH	ROD DIA. (mm)	CURRENT A	MELTING RATE I/min	*3 WELDING SPEED I/min	ARC TIME Min/Rod	B Min/M	ROD SPENDING lbs/M	*4 POSSIBLE MACHINE No./Man.	*5 ROD JOINTS No./km	*6 WORK TIMES Hr/5W/km
1.8	27.6" (700mm)	45.2" (1150) mm	7/32	6	260	7.5	11.2	3.4	2.9	0.53	5	870	4.9
			1/4	7	310	7.3	11.0	3.4	3.0	0.72			5.0
			9/32	7.5	330	7.0	12.6	3.6	3.1	0.80			5.3
	35.4" (900mm)	59" (1150) mm	1/4	7	300	7.0	12.6	4.7	3.1	0.69		670	3.8
			9/32	7.5	320	6.9	12.5	4.8	3.2	0.75	7		3.8
			5/16	8	340	6.7	12.0	5.0	3.3	0.86	8		3.5
1.3	27.6" (700) mm	32.7" (830) mm	3/16"	4.5	190	9.2	12.0	2.7	3.3	0.5	1	1205	27.4
			7/32"	5	220	8.2	10.6	3.1	3.7	0.57			30.9
			1/4"	6.0	280	8.1	10.6	3.1	3.7	0.75			31.1
			9/32"	6.4	300	8.0	10.4	3.1	3.8	0.84			31.4
			5/16	7.5	350	7.5	9.7	3.4	4.1	1.06			33.7
			11/32"	8.	380	7.3	9.5	3.4	4.1	1.22			34.4

REMARKS:

*1 Speed Ratio = $\frac{\text{Bead Length (inch)}}{\text{Melting Length (inch)}}$

*2 Bead Length(inch) = (Rod Length − 2.36" (60 mm)) x Speed Ratio

*3 Welding Speed (inch/min) = Melting Rate x Speed Ratio

*4 Possible Machine (No./Man) = 1 + $\frac{\text{Arc time}}{\text{Rod Joint Time}}$

*5 Rod Joints
Number of Setting Rod of weld length 3280 feet(1000m) = $\frac{\text{Weld Length (3280 feet)}}{\text{Bead Length (*2 feet)}}$

*6 Work times = $\frac{\text{Weld length (3280 feet or 1000m)}}{\text{Welding Speed x possible machine x arc time ratio (0.4) x worker (5) x 60}}$

SET CONDITION EXAMPLE

Arc time ratio: 40%
Weld length : 3280 feet (1000 m)
Workers : 5
2.36: Remain Electrode
Rod Joint Time: 0.7 minute

Comparison of gravity arc welding and manual welding

III MARINE TECHNOLOGY, INC.

Ref. No. HP-033
March 2, 1979

VERTICAL DOWN WELDING

1. OUTLINE

Vertical down welding process is specifically designed low hydrogen type electrode and high working efficiency vertical welding.

Applicable parts are sub-assembly stage, assembly stage and erection stage.

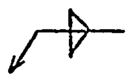
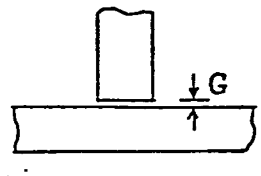
2. CHARACTERISTICS

(1) The deposited metal contains less hydrogen. Its crack resistance is as good as that of the conventional low hydrogen type electrode.

(2) Manipulation is easier in vertical down welding than in upward, and considerable higher current is available in vertical down welding without any defects such as undercut, overlap, etc., assuring extremely high working and joint efficiency.

(3) Both one-pass and multi-pass welding are easily performed in the vertical down welding.

3. APPLICABLE CONDITION

WELDING SYMBOL	EDGE PREPARATION	STANDARD GAP	ALLOWABLE LIMITATION
		G = 0	G ≤ 1/8" * (3.2 mm)

* Weld leg length shall be increased by gap

4. WELDING EQUIPMENT

Welding Power Sources: AC 500A ~ 400A 60 Hertz

5. WELDING MATERIALS

	ELECTRODES		REMARKS
Ordinary Strength Steel	AWS E 7016	4.0 4.5 5.0 5.5 6.0 x 17.7" (450) mm * LB26V S 16V	Made by Kobe Steel, LTD Nippon Steel, LTD etc.
71,000 PSI Higher Strength Steel	AWS E 7016	4.0 4.5 5.0 5.5 6.0 x 17.7" (450) mm * LB52V	"

* Example

6. TACK WELDING

Electrode: E7016 - 5/32"
Tack Weld Length: standard 2" In case of H.T. ≥ 2"
Pitch: ab. 12 ~ 16"
Position: vertical down

7. WELDING PREPARATIONS

(1) Weld area shall be free of all oil or grease, excessive rust or scale by brush up, and moisture by heating.

(2) For the low hydrogen electrode should be dried at a temperature of 580°~ 660°F for one hour before use.

8. STANDARD WELDING CONDITION

Leg Length \ Rod Dia / Current	4.5 mm φ	5.0 mm φ	5.5 mm φ
	230 A	270 A	310 A
3/16" (4.8 mm)	1Lay 1Pass	1Lay 1Pass	1Lay 1Pass
1/4" (6.4)	2Lay 3Pass	2Lay 3Pass	2Lay 2Pass
9/32" (7.1)	2Lay 3Pass	2Lay 3Pass	2Lay 2Pass
5/16" (7.9)	3Lay 4Pass	2Lay 3Pass	2Lay 3Pass
11/32" (8.7)	3Lay 5Pass	3Lay 4Pass	3Lay 4Pass
13/32" (10.3)	4Lay 7Pass	4Lay 7Pass	3Lay 5Pass

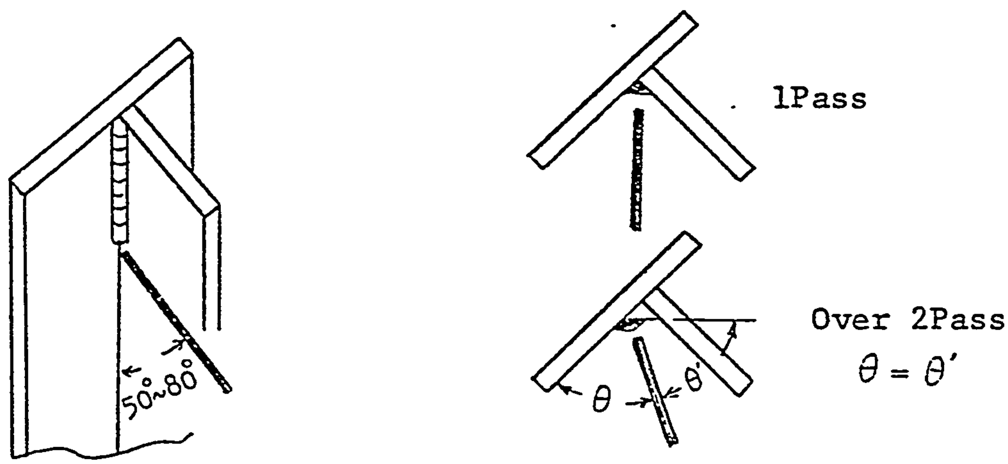
9. MANIPULATION TECHNIQUE

(1) Manipulation of electrode

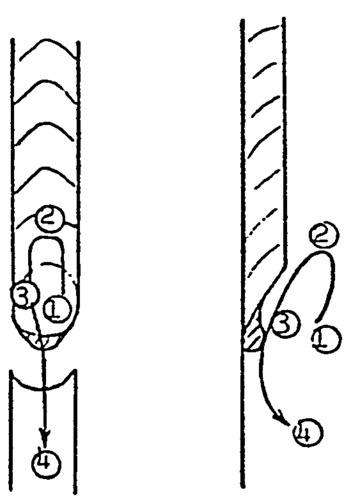
Hold the electrode. Press its tip against mother plate.
Operate by straight bead method without weaving.
Welding speed to be suitably adjusted by leg length
and electrode's tip to be always preceded prior to molton slag

(2) Angle of electrode

As shown in the sketch



(3) Interrupting arc



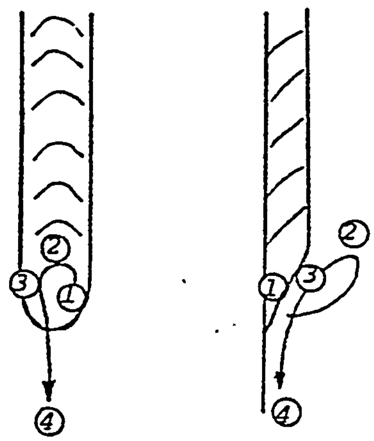
① Electrode to be held as if tip is floated on upper si crater

② Soft touch

③ Pressing its tip against c

④ Blow away deposited metal before coagulation by arc cut off arc.

(4) Re-arc starting



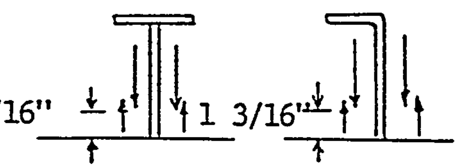
① Arc touch on crater

② Move the tip of electrode swiftly till upper side of crate

③ Push electrode and enough fuse on the crater

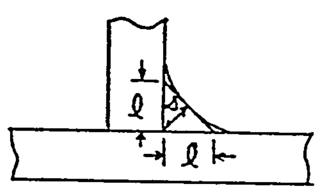
④ Welding by proper speed

(5) Treatment of lower part: The lower part of vertical down welding shall be carried out by upward welding, its length is 1 3/16" (30mm) from lower end.



10. CORRECTING METHOD

(1) Leg length



Allowable Limitation

$0.9L \geq \ell$ L: Regulation leg lengt

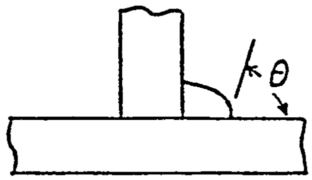
$0.9S \geq s$ S: Regulation throat-thickness

Less than 0.9L (0.9S) to be amended by welding

(2) Under cut of bead

Depth of undercut: up to 1/64" (0.5mm)

(3) Overlap of bead



$\theta < 90^{\circ}$: To be chipped by grindi
or to be amended by
welding

(4) Pit of bead

No Permission : To be chipped by gouging
and to be amended by welding

11. INSPECTION

Bead appearance inspection

Item 10-(1)~(4) , etc. Check by gauge and vision.

REFERENCE DATA FOR VERTICAL DOWN WELDING

Comparison of Vertical Upward Welding and Vertical Down Welding

Leg Length \ Welding Method	Upward Welding (Min/M)	Vertical Down Welding (Min/M)	
		4.0 Φ	5.0 Φ
3/16" (4.8 mm)	8	3.5	2
7/32" (5.6)	9	4	2.5
1/4" (6.4)	11	5.5	4
9/32 (7.1)	12	6.5	4.5
5/16 (7.9)	14	9	6
11/32 (8.7)	16	10.5	7.5
3/8 (9.5)	17.5	11.5	8
13/32 (10.3)	20	13	9.5
7/16 (11.1)	22	14	11
15/32 (11.9)	25	15.5	14

Remark:

(Min/M): Minute per 3.28 feet (Meter) of net arc time

Ref. No. HP-086
May 2, 1979

WELDING PROCEDURE OF 50 Kg/mm^2 (71000 PSI) HIGH-STRENGTH STEEL

I. CONSTRUCTION STANDARD

1. IDENTIFICATION OF HIGH- STRENGTH STEEL (H. T .)

To be painted with green primer paint.

2. MARKING

Cold chisel and punch are not to be used. (If they were used by mistake, final grinding or welding after 100°C (210°F) pre-heating and final grinding should be carried out)7

3. GAS-CUTTING

When gas-notches are found more-than 0.5mm in depth at the free edge of the plate used just after being gas-cut final grinding or welding after 100°C (210°F) pre-heating and final grinding should be carried out.

4. BENDING PROCESS

It is better that bending be done with the press. When line heating is used, the temperature should be-less or equal to 650°C (1200°F) and cooling with water may be used.

ln this *case,* the temperature must be checked by temperature chalk (tempil stick).

5. WELDING MATERIAL

TABLE 1 MANUAL WELDING

Classification of Use		Position	Electrode	Notes
A	General Welding	All Positions	AWS E 7018	Includes AH32, DH32 AH36, DHN36, EH36, also plate listed under E6011. EH32 is also incl.
B	Vertical Down Welding	Vertical	E 7016	Includes AH32 thru EH32, also ABS plate listed under E6011
C	Flat and Horizontal Fillet Welding	Flat and Horizontal Fillet	E 7018 E 7028	Includes AH32, DH32 DHN32, AH36, DH36, DHN36
D	Butt joint of Flat and Horizontal	Flat and Horizontal	E 7018	Same as A
E	Seam of side shell (HT x MS)	Horizontal	E 7018	Same as A
F	Fillet welding of overhead	Overhead	E 7018	Same as A
G	Correct Welding	All	E 7018	Same as A
H	Tack Welding	All	E 7018	Same as A

Table 2 Automatic Welding Materials

Welding Method	Filler Wire	Flux	T	Grade
Both sided submerged arc welding	L-61	# 780	≤ 1"	ALL HS except EH grade
	L-61	# 860	< 3"	All
Combined submerged arc welding	L-61	# 860	< 3"	All

In case of HT x MS to be used above material.
In case of # 780 Flux to be applied only one pass welding.

6. WELDING MATERIAL CONTROL

(1) Dryness control for manual welding electrodes.

(a) Electrodes to be dried one hour from 300°C (570°F) to 350°C (660°F) before use.
(b) After drying is performed in the above-mentioned way, electrodes may be used in keening bob of which temperature is from 100°C (210 F) to 150°C **(300°F)** .
(c) Electrodes which are taken out from the above-conditioned box are to be used within five hours. When electrodes are taken out in a portable dryer, they are to be used within ten hours.
(d) When electrodes are kept out over above-mentioned time limit, they are to be re-dried on condition (a).
(e) To check out-keeping time, it is necessary to distinguish electrodes by painting end of electrodes as follows:

Table 3 End Color of Electrode

	Forenoon	Afternoon
Odd number day	Green	Black
Even number day	White	Yellow

(2) Welding Material for automatic welding.

In case that welding materials are newly used from closed container, they may be used just as it is within 12 hours. But all should be re-dried if kept out from the previous day. The welding materials which are kept out more than twelve hours after container-opened, should be re-dried at 250°C (480°F) more than 1 hour.

7. PRE-HEATING AND BUILDUP METHOD CONTROL

Pre-heating and especially buildup method are as shown in Table 4.

Table 4

Work Division (Division / Period)		Pre-heating Method: Cold weather season Nov.1~March 31	Pre-heating Method: Other	Service Bead Method: Cold weather season Nov.1~March 31	Service Bead Method: Other
A	Horizontal Butt welding Ht x HT, HT x MS	Pre-heating over 100°C (210°F)	Pre-heating over 75°C (167°F)	Service bead after Pre-heating over 75°C (167°F)	Service bead without Pre-heating
B	Overhead fillet welding				
C	Vertical Down Welding	When electrodes less than 4.5mm are used, at an ambient temperature of 5°C (41°F) or less, plates are to be pre-heated to 75°C (167°F) or more before first pass.			
D	Butt Welding	When electrodes are used at an ambient temperature of 5°C (41°F) or less, and to 25mm (1") or more in plate thickness, plates are to be pre-heated to 75°C (167°F) or more before first pass.			

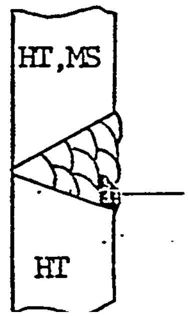
(In Divisions A and B, generally service bead methods are used.)

Notice:

(1) Pre-heating in division A is performed before first pass of finish layer. But if that interlayer temperature is higher than pre-heating temperature, it is unnecessary to pre-heat. (as shown in Fig. a)

(2) Pre-heating in Divisions B, C and D are performed before first pass.

(3) ervice bead in Divisions A and B are put below in igs. (b) and (c).



Fig, (a) Pre-Heating

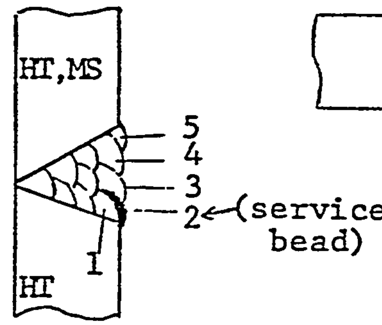


Fig. (b) Service Bead

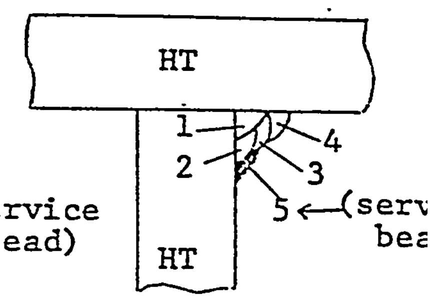


Fig. (c) Service Bead

(4) In welding of Divisions A and B, block welding less than one meter is to be used. But only in Division A may block welding less than one meter be used after welding is finished as far as two-thirds of thickness.

(5) Pre-heating is to be carried out to 100mm (4″) each side from welding line in principle.

(6) Check of heating temperature to be performed each side 50mm (2″) from welding line by temperature chalk.

(7) In principle in gravity welding and submerged arc welding, it is unnecessary to pre-heat, it is advisable to gas-heat before welding to remove rust, water, oil and paint from the surface to be welded.

8. <u>ARC STRIKE AND SHORT BEAD</u>

(1) Do not arc strike except in welding groove.

(2) Welding bead length is to be more than 50mm (2″) and short bead less than 50mm (2″) is not to be put even in tack welding and in repair welding.

(3) When above-mentioned arc strike or short bead is put on plate by mistake, post-heating 500°C (930°F)~650°C (120 is to be performed or welding is to be carried out in lengt more than 50mm (2″) after beads are ground out, and root crack and heel crack are checked.

9. TACK WELDING AND REPAIR WELDING

Electrodes are to be 50 kg/mm^2 (71,000 PSI) high-strength steel and notices in regular welding are to be applied.

10. EDUCATION .

Fitter and welder who treat H.T. are to be given the appointed education and to affix the authorized mark on the cap which shows the completion of education.

11. INSPECTION

General inspections are the same as with mild steel, but especially the following is to be paid attention to.

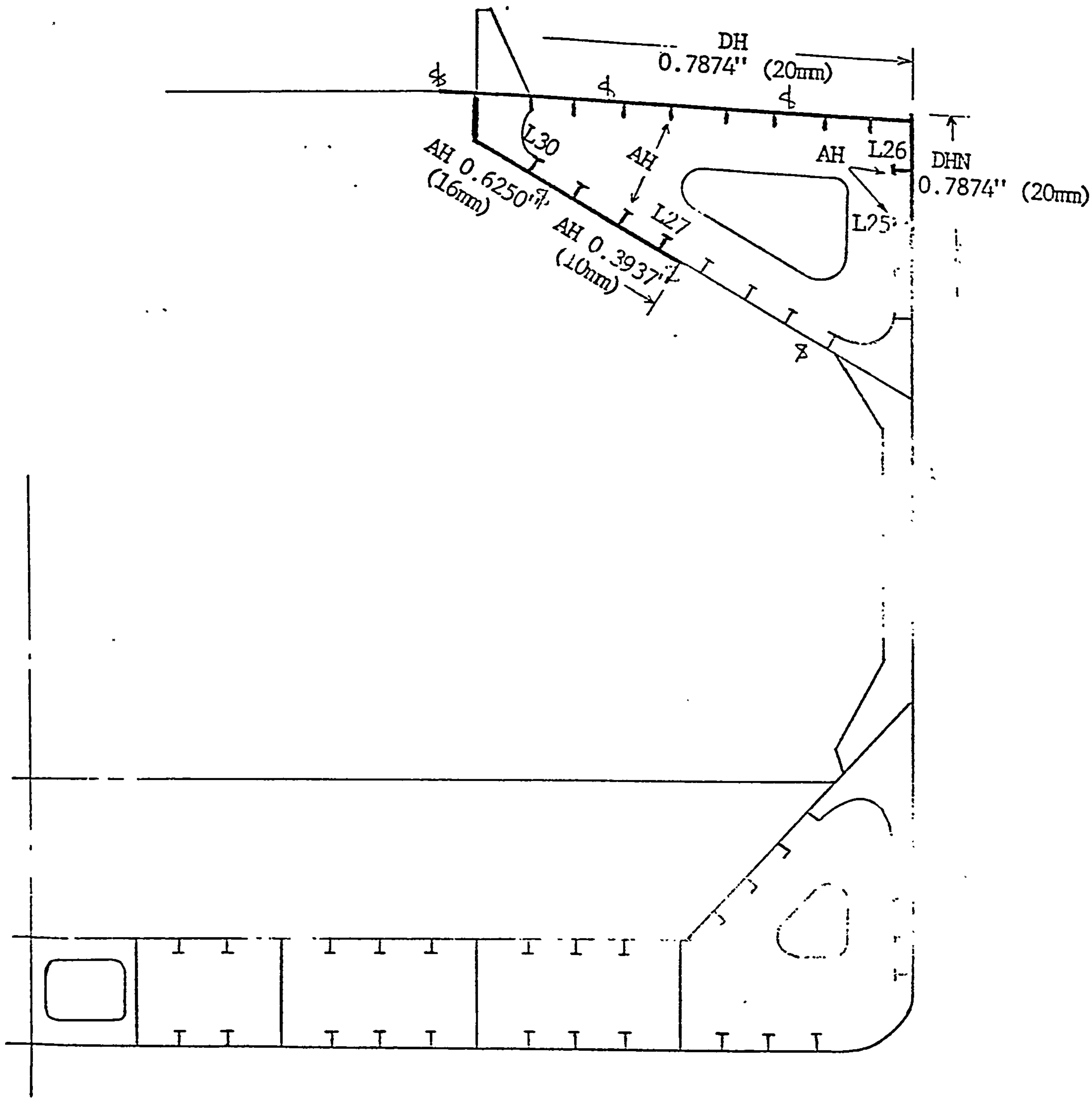
(1) Arc strike and short bead
(2) In work divisions A and B on Table 4, magnetic particle test or penetrant test are to be carried out for all welding length.

12. OTHERS

(1) Gravity welding is to be carried out after removal of zincrich paint on welded area
(2) All pieces are to be mild steel and in fitting them to H.T., notices in regular welding are to be applied.
(3) In Removal of pieces, gas gouging or-grinding after gas-cutting is to be carried out instead of using hammer.
(4) If there is a little water on the plate, absolutely do not weld. H.T. is especially sensitive to cracking when there is water.
(5) If mild steel electrode is misused on high-tensile ste the welded place is to be chipped out to 2mm (5/64") . from plate face in depth and to be re-welded.
(6) Welding speed in first pass of the butt joint is to be *slow as* possible to prevent cracking. Where the gap is, it is especially necessary to complete backing strips and slow welding speed are to be secured.

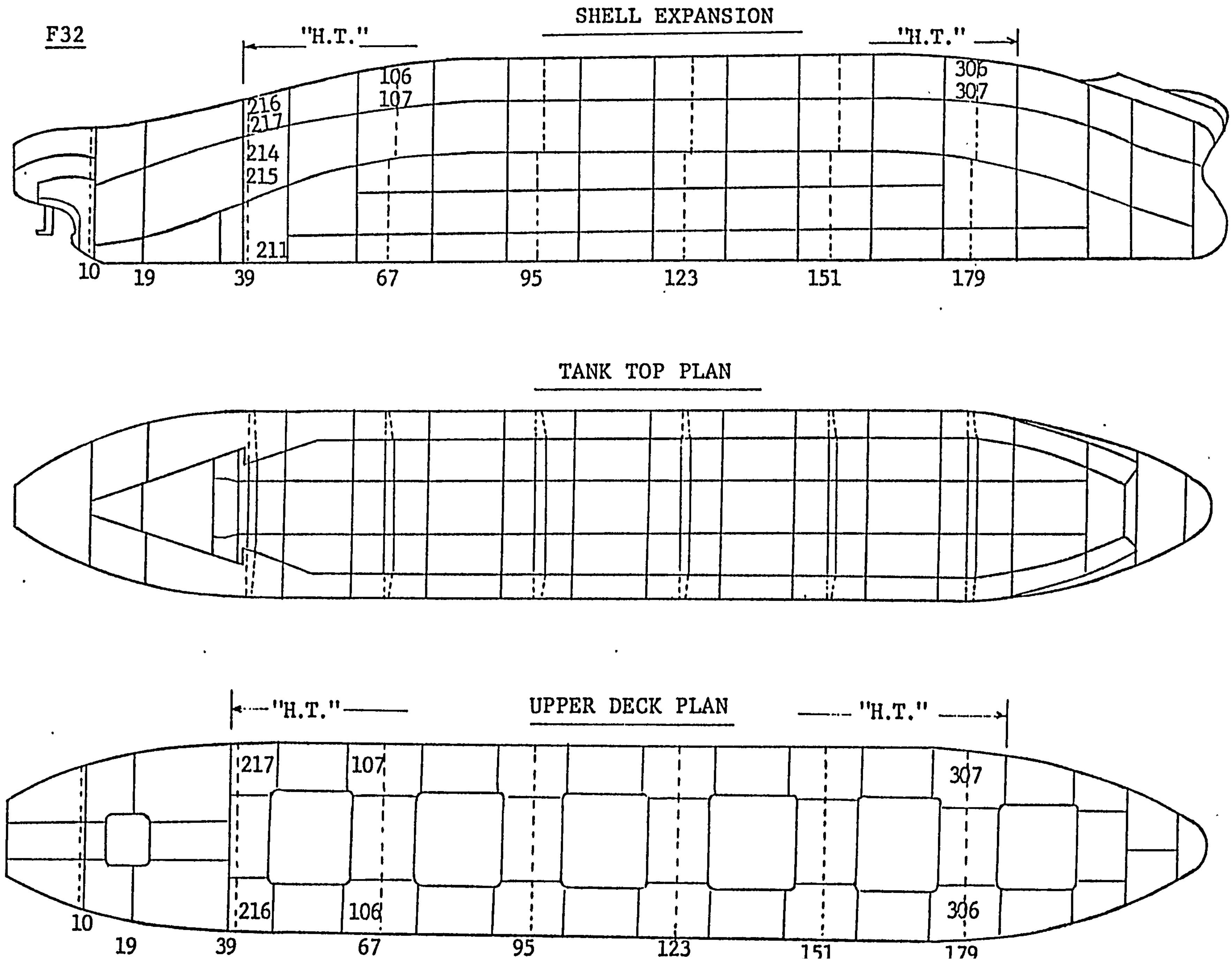
APPLICATION PARTS OF HIGH STRENGTH STEEL

: HIGH STRENGTH STEEL



MIDSHIP SECTION

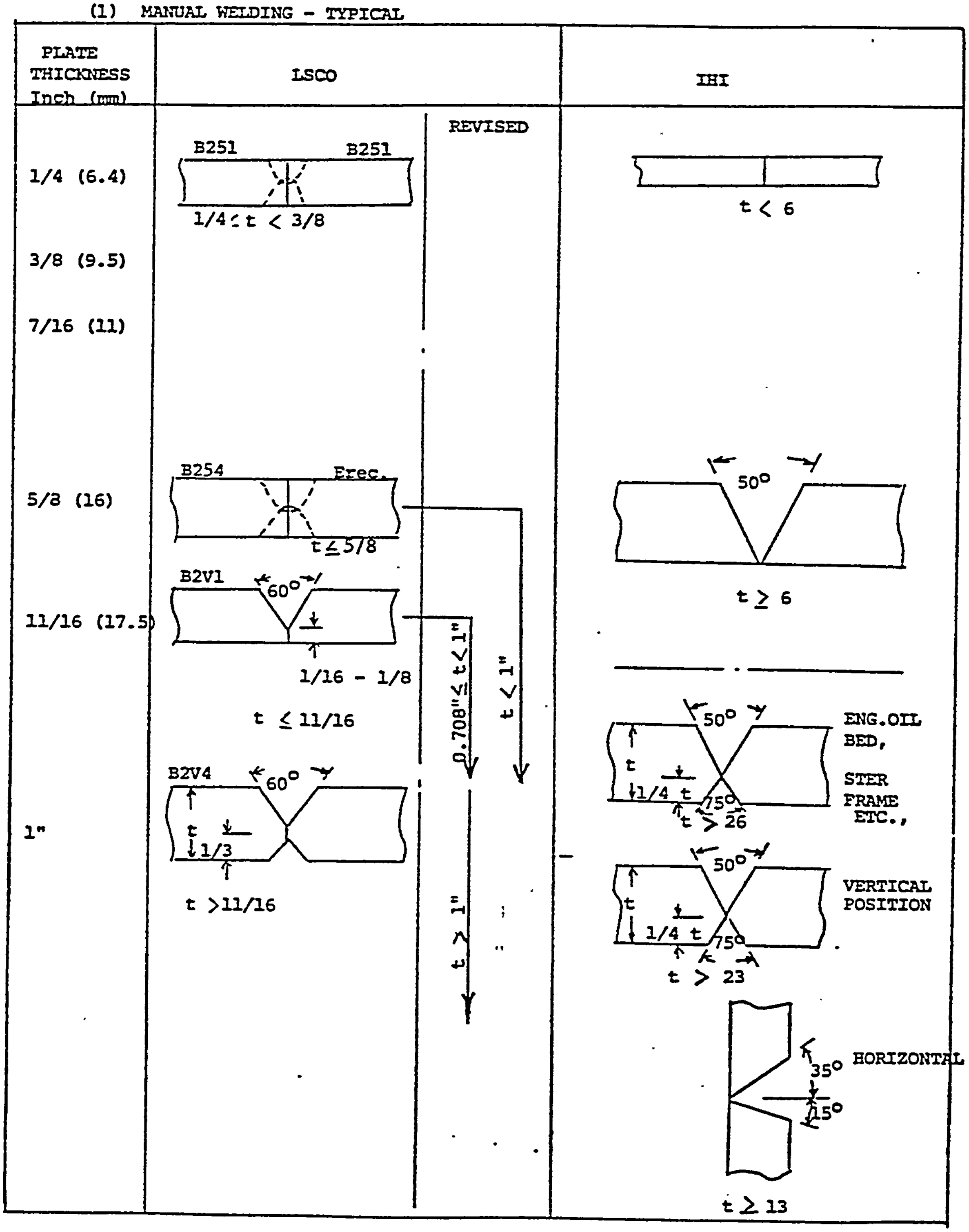
F32


SHELL EXPANSION
"H.T."
"H.T."
216
217
214
215
211
106
107
306
307
10
19
39
67
95
123
151
179
TANK TOP PLAN
UPPER DECK PLAN
"H.T."
"H.T."
217
107
307
216
106
306
10
19
39
67
95
123
151
179

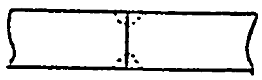
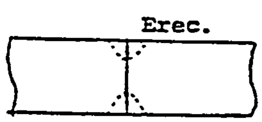
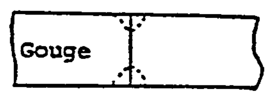
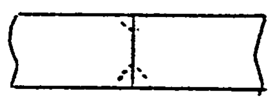
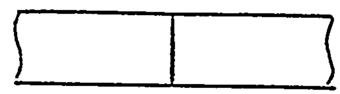
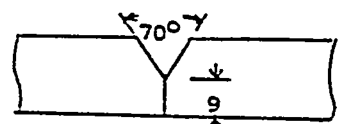
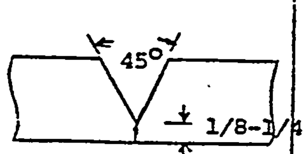
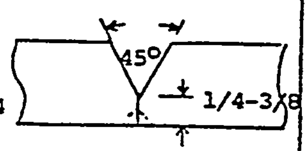
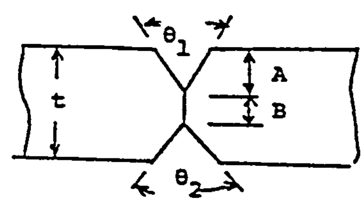
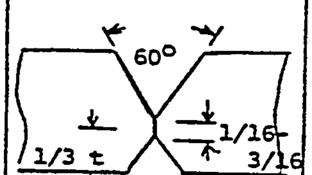
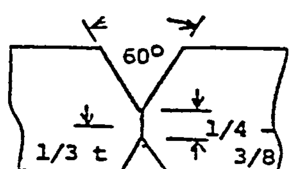
4. DIFFERENT AREAS OF WELDING BETWEEN LSCO AND IHI

4.. A. EDGE CONDITION

(1) MANUAL WELDING - TYPICAL

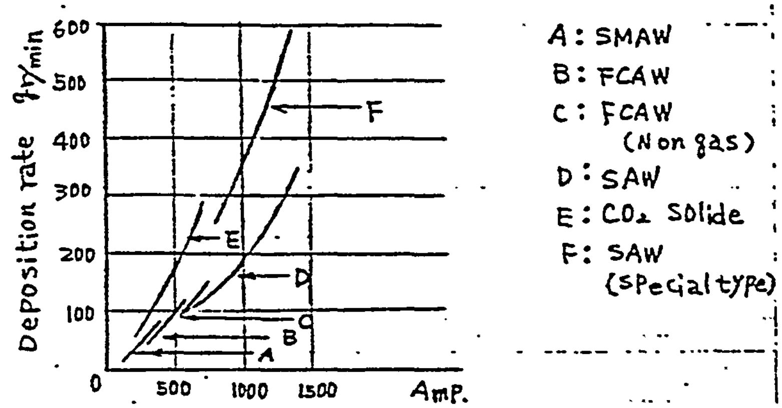


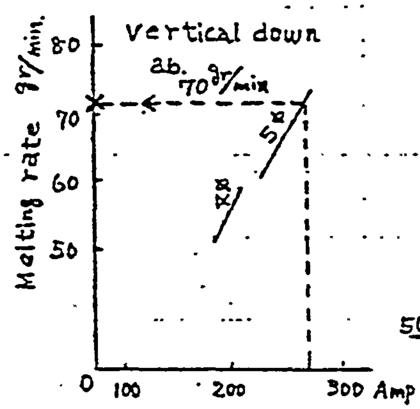
(2) SUBMERGED ARC WELDING - TYPICAL

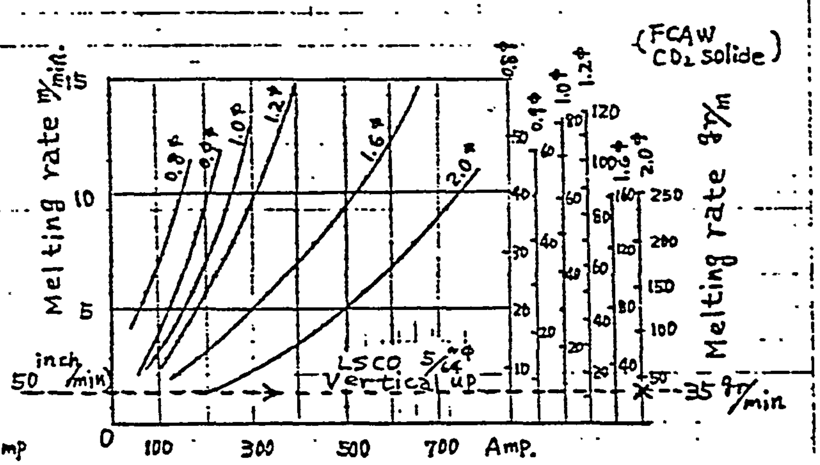
PLATE THICKNESS INCH (mm)	LSCO	REVISED	IHI (AIOI)
1/4" (6.4) 7/16" (11)	 $1/4 \leq t \leq 7/16$		
1/2 5/8 (16)	 $1/4 \leq t < 5/8$	 $7/16 \leq t \leq 5/8$  $t \leq 0.708"$	 $t \leq 17/32$  $9/16 < t \leq 21/32$
1" (25.4)	 $1/2" \leq t < 1"$	 $0.708" < t < 1"$	 11/16 t 1-17/32 $\theta_1 = 70°$ $\theta_2 = 90°$
	 $t > 1/16"$	 $t > 1/16"$	(see table below)

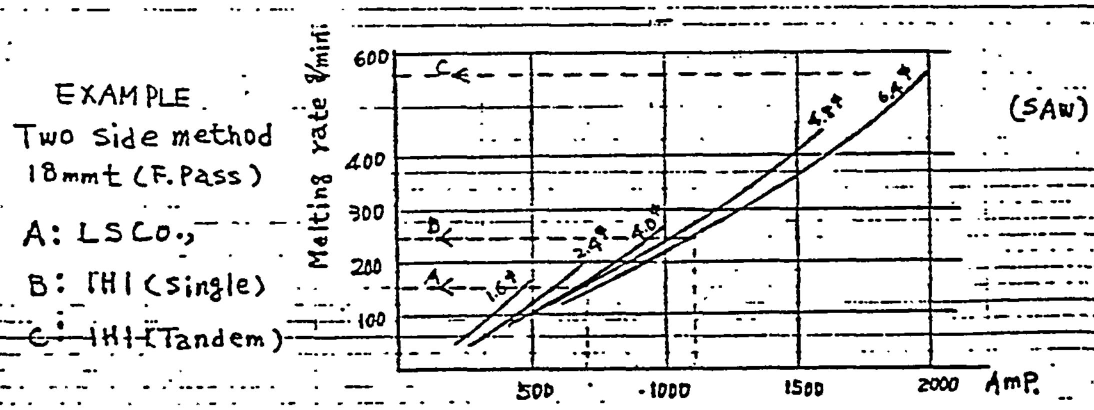
T	A	B
11/16-25/32	0.24"	0.24"
13/16-31/32	9/32	9/32
1 - 1-1/16	11/32	9/32
15/32 to 1-9/32	13/32	11/32
1-11/32 to 1-13/32	15/32	7/16
1-7/16 to 1-1/2	9/16	7/16

4. B. WELDING CURRENT









4. C. WELDING METHOD

STAGE	JOINT NO.	LSCO	IHI
ASSEMBLY	1	Two-sided submerged arc welding	F.C.B. or R.F. one-sided welding
	2	"	"
	3	Manual welding	Combined CO_2 one-sided and submerged arc welding
	4	"	Nothing
	5	Two-sided submerged arc welding	Same as 1
	5'	Manual welding	CO_2 one-sided semi-auto (Erec. Joint)
	6	Two-sided submerged arc welding	Same as 1
	7	"	"
	8	"	"
	9	"	"
ERECTION	1	Combined manual and submerged	CO_2 one-sided semi-auto.
	2	Manual welding	Manual welding
	3	Same as 1	Fab one-sided welding
	4	Manual welding	Manual welding
	5	"	"
	6	Manual or FCAW	FCAW and manual welding
	7	Manual welding	Electro gas arc welding
	7'	"	Manual welding
	8	"	CO_2 one-sided semi-auto.
	9	Same as 1	Combined CO_2 one-sided & submerged arc welding
	10	Manual or FCAW	CO_2 one-sided semi-auto.
	11	Manual welding	CES welding
	12	Manual welding	Manual welding

4.D. PRODUCTION PLANNING

(1) Production Planning by Welding Engineers

From the initial stage of the basic design, welding engineers must study the welding application to assembly stage and especially to the erection stage.

After pre-hull blocking meeting, the welding application Plan will be prepared for the development of working *drawings.* Also, concurrently with production engineers, through the production planning, the production sequence will be assured by welding engineers.

(2) Welding Sequence Approval

Once intending to apply the new welding method or to change the application, it is *necessary to* take the permission from the regulatory after the confirmation of the procedure test in our laboratory. Regarding the above situation, and also in order to maintain the adequate welding sequence and method, the following items will be taken into consideration by the welding engineering group.

(a) Welding standard
1. Edge condition standard
2. Welding material application standard with brand name

(b) Welding Manual in general

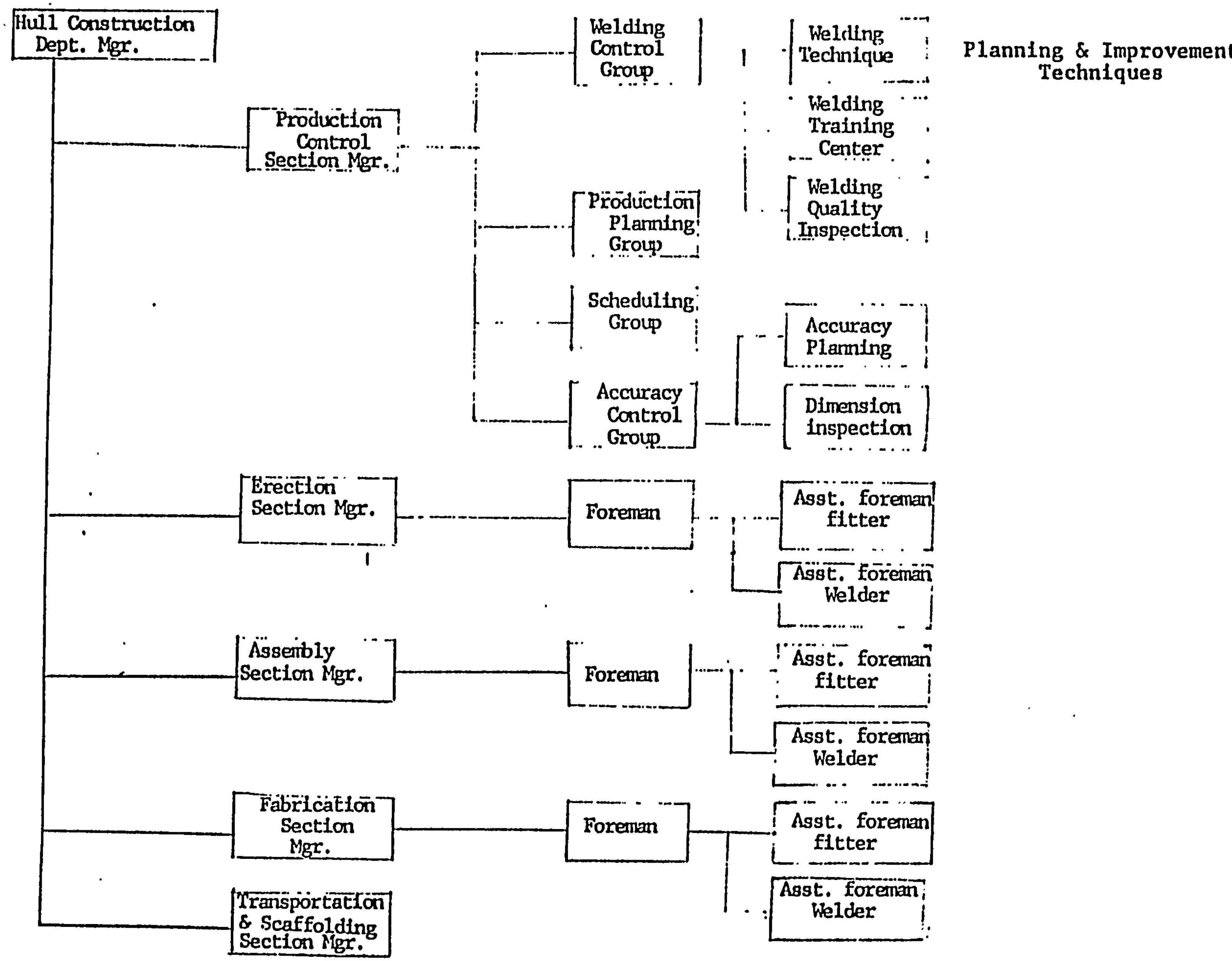
(c) Welding Manual for each welding method

After establishing or changing the above standard and/or manual, welding engineers will take the responsibility to inform the design and production engineers and then educate the welder and, if necessary, the fitter.

E. ORGANIZATION

Our principle of organization for hull construction is the basis of the production process and/or stage, in order to meet the production flow instead of the craft. In this connection, welder craft is especially distributed into subassembly in fabrication, assembly and erection respectively. However, *in* order to keep and improve the welding$technique, the welding control group of hull production control section assists the construction manager for welding field especially.

ORGANIZATION OF HULL CONSTRUCTION IN A101



9. RECOMMENDATION

A. How to Achieve Good Quality

First of *all we* can say that the quality of hull steel structures depends on the quality of welding joints. Assurance of welding quality is related to *several* items as shown in Fig. Most items should be confirmed by the company's own laboratory testing and taken into consideration with welding engineers.

(1) Welding laboratory functions.

To establish the functions of welding laboratories, it will assure the welding quality *as* foIlows:

Technical research
Method improvement
Procedure test and approval test
d. Education and training

Through the above functions, the welding engineer has the responsibility for welding quality.

(2) Welding standard and welding manual.

In order to keep the adequate level of welding quality, the welding standard and welding manual of each applied welding method, in which the mechanical characters are confirmed by the company's own laboratory testing, should be established and given to welders in the form of a handbook. It is essential. to maintain the same procedure in the actual field instead of the individual method.

(3) Edge preparation of the butt joint.

The standard edge condition of each plate thickness should be established for each welding method, laboratory testing. Each edge of the joint should be prepared with the burning machine as much as possible prior to fitting the joint. In this connection, the accuracy control activity, now set up in LSCo, will be helpful in promoting the above matters.

(4) Submerged arc welding.

In setting up the standard manual, it is necessary for the following:

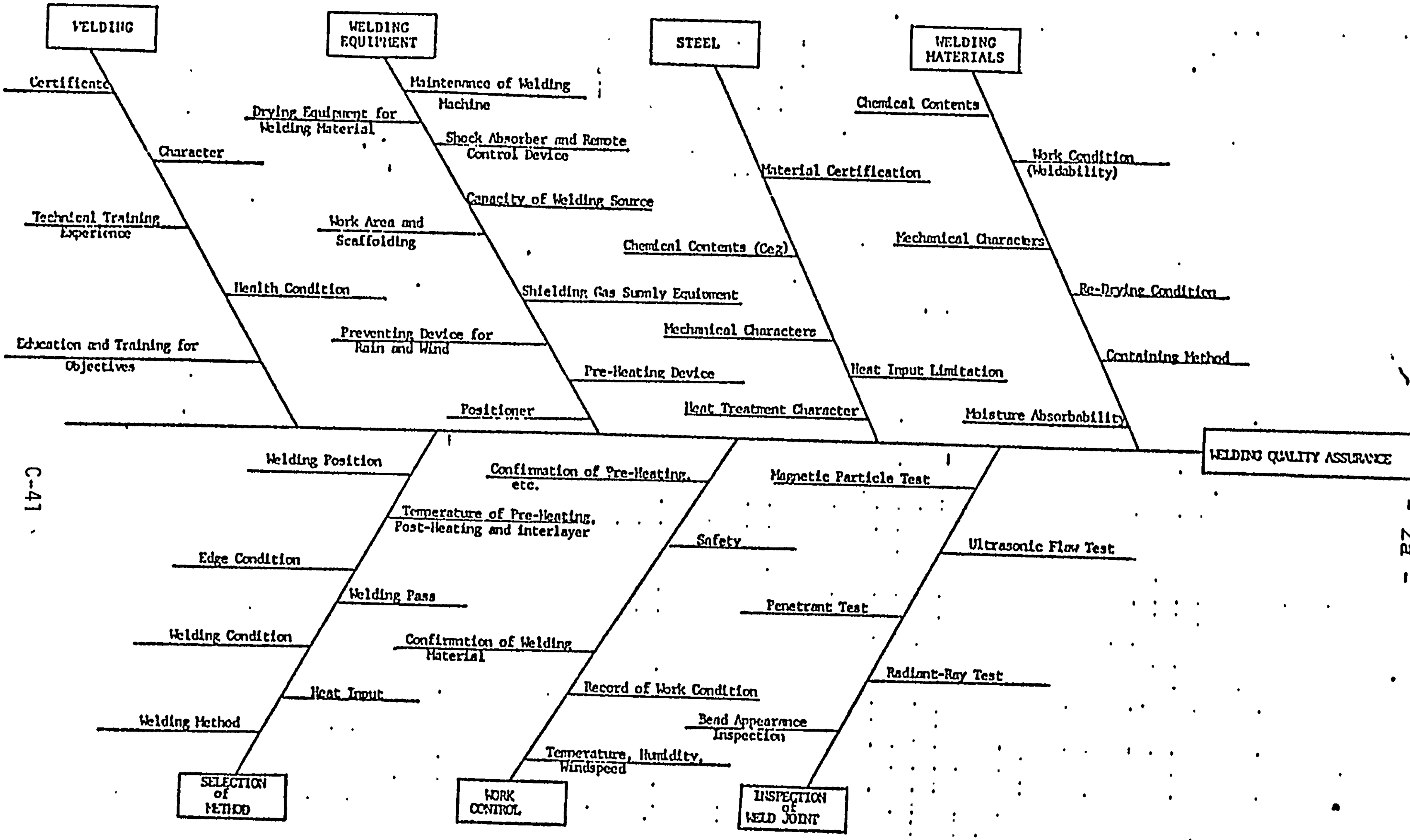
a. Welding condition of each plate thickness
b. Standard run-off tab plate
c. Macro-etching test of each end

9. RECOMMENDATION (cont.)

(5) AC arc welding machine.

The AC arc welding machine should be equipped with a remote control device in order to automatically control the current when adjusting rod size and/or welding positio

WELDING TECHNICAL CONTROL -- SPECIFIC FACTOR CHART



B. How to Achieve High Efficiency

1. Gravity Welding Method and Vertical Down Welding for Fillet Joint.

The joints in hull steel structure consist of.butt joint and fillet joint. Each joint is classified into either flat, vertical, horizontal or overhead, according to the working position.

In this connection, manual welding performance" standards in IHI are shown in Tables 1 and 2 for each joint and each position as hours per meter.

Through Production Planning, hull steel structures are divided into units and the unit is further divided into components and pieces. In other words, hull steel structures are built up from piece to unit through the said processes; sub-assembly, assembly and erection. Welding performance of assembly and erection is different, as shown in Fig. A.

From the above data, the following tendency of welding performance standards are defined basically.

1. Fillet joint > Butt joint
2. Flat position > Vertical position > Overhead position
3. Sub-Assembly Stage > Assembly Stage > Erection Stage

On the other hand, the welding length distribution is shown in Table 3, as an example According to this table, the following three items equal about 70 percent of all welding length.

1.	Flat fillet welding on sub-assembly:	30%
1.	Flat fillet welding on assembly	26%
3.	Vertical fillet welding on assembly:	15%

In order to achieve the high productivity in welding, it is essential to improve the productivity of the above three major portions. For the above portion, the simplest and most effective welding method of the above portion are "gravity welding method" for Items 1 and 2, and "vertical down welding method" for Item 3.

From this viewpoint,. it is necessary for welding engineers to involve production planning from the initial planning.

(2) Submerged arc welding for butt joints.

(a) One-pass welding method for two sides on the panel assembly. Welding sequence standards *are* shown in Tables 4 and 5 for single submerged machines and tandem submerged arc welding machines.

(b) Combined method with CO_2 semi-auto welding on erection stage and curved assembly stage.

Welding sequence standards are shown in Table 6 for combined method with CO_2 semi-auto welding.

HOUR/METER (3.28 FEET)
OF BUTT JOINT
TABLE 1

Plate Thickness (mm)	Plate Thickness (inch)	FACE SIDE F	FACE SIDE H	FACE SIDE V	FACE SIDE O	FACE SIDE + BACK SIDE F	FACE SIDE + BACK SIDE H	FACE SIDE + BACK SIDE V	CO_2 one side F
8	5/16	0.5	0.7	1.0	1.0	1.3	1.4	1.9	
9		0.5	0.9	1.2	1.2	1.3	1.6	2.1	
10		0.6	1.0	1.3	1.3	1.4	1.7	2.2	0.83
11	7/16	0.6	1.1	1.5	1.4	1.4	1.8	2.4	0.9
12	15/32	0.7	1.2	1.6	1.6	1.5	1.9	2.5	0.95
13		0.8	1.3	1.8	1.8	1.6	2.0	2.7	1.0
14	9/16	0.9	1.5	2.0	2.0	1.7	2.2	2.9	1.1
15	19/32	1.0	1.7	2.2	2.3	1.8	2.4	3.1	1.15
16	5/8	1.1	1.8	2.4	2.5	1.9	2.5	3.3	1.23
17		1.2	1.9	2.7	2.8	2.0	2.6	3.6	1.3
18	23/32	1.3	2.0	2.9	3.1	2.1	2.7	3.8	1.4
19	3/4	1.4	2.2	3.1	3.4	2.2	2.9	4.0	1.5
20	25/32	1.5	2.4	3.4	3.7	2.3	3.1	4.3	1.6
21		1.6	2.5	3.6	4.0	2.4	3.2	4.5	1.7
22	7/8	1.7	2.7	3.9	4.3	2.5	3.4	4.8	1.7
23	29/32	1.8	2.8	4.1	4.6	2.6	3.5	5.0	1.8
24	15/16	1.9	3.0	4.4	5.0	2.7	3.7	5.3	2.0
25		2.0	3.2	4.7	5.3	2.8	3.9	5.6	2.1
26	1 1/32	2.1	3.4	5.0	5.7	2.9	4.1	5.9	2.2
27	1 1/16	2.3	3.6	5.2	6.1	3.1	4.3	6.1	2.3
28	1 3/32	2.4	3.8	5.5	6.5	3.2	4.5	6.4	2.4
29		2.6	4.1	5.9	7.0	3.4	4.8	6.8	2.6
30	1 3/16	2.7	4.4	6.2	7.5	3.5	5.1	7.1	2.7
31	1 7/32	2.8	4.7	6.6	8.0	3.6	5.4	7.5	2.9
32	1 1/4	3.0	5.0	7.0		3.8	5.7	7.9	3.0
33		3.2	5.3	7.4		4.0	6.0	8.3	3.2
34	1 11/32	3.4	5.6	7.8		4.2	6.3	8.7	3.3
35	1 3/8	3.6	5.9	8.2		4.4	6.6	9.1	3.5

Back Side	H	V	O	Plate Thickness to Be Used 8 mm
	0.7	0.9	0.8	

Gouging hours not included

HOUR/METER (3.28 FEET) OF FILLET JOINT
TABLE 2

Leg Length		FILLET WELDING			
mm	inch	F	V	VD	O
5		0.2	0.4	0.2	0.3
5.5	7/32	0.2	0.4	0.2	0.3
6		0.2	0.5	0.2	0.4
6.5	1/4	0.2	0.5	0.2	0.4
7	9/32	0.2	0.6	0.2	0.5
7.5		0.2	0.6	0.3	0.5
8	5/16	0.2	0.7	0.3	0.6
8.5	11/32	0.3	0.7	0.3	0.7
9		0.3	0.8	0.4	0.8
9.5	3/8	0.4	0.9	0.4	0.9
10		0.4	0.9	0.4	0.9
10.5	13/32	0.4	1.1	0.5	1.1
11	7/16	0.4	1.1	0.5	1.1
11.5		0.5	1.2	0.6	1.3
12	15/32	0.5	1.2	0.6	1.3
12.5	1/2	0.6	1.4	0.7	1.4
13		0.6	1.4	0.7	1.4
13.5	17/32	0.7	1.6	0.8	1.7
14		0.7	1.6	0.8	1.7
14.5	9/16	0.8	1.7	0.9	
15	19/32	0.8	1.7	0.9	
15.5		0.8	1.8	1.0	

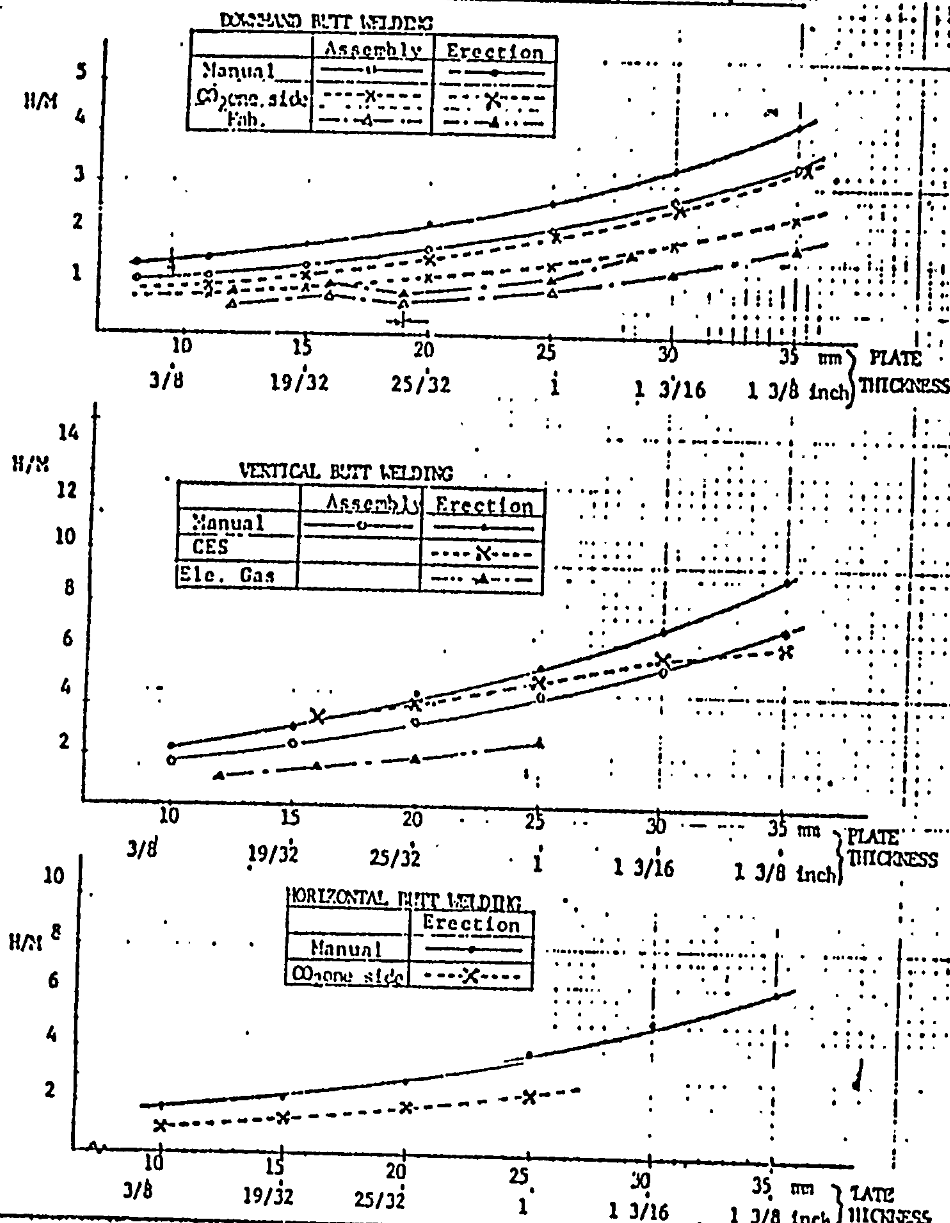
TABLE 1

F: 50°V, GAP 2mm 4.5ϕ, 5ϕ, 6ϕ, 7ϕ
V: " " 4.5ϕ
H: " " 4.5ϕ, 5ϕ, 6ϕ
O: " " 4
CO_2: " GAP 4mm 1.6ϕ

TABLE 2

F: 90° GAP 0mm 5ϕ, 6ϕ, 7ϕ,
V: " " 4.5ϕ
VD: " " 5.5ϕ
O: " " 4.5ϕ

HOUR/METER (3.28 FEET) OF BUTT JOINT FOR ASSEMBLY, ERECTION



HOUR/METER (3.28 FEET) OF FILLET JOINT FOR ASSEMBLY, ERECTION

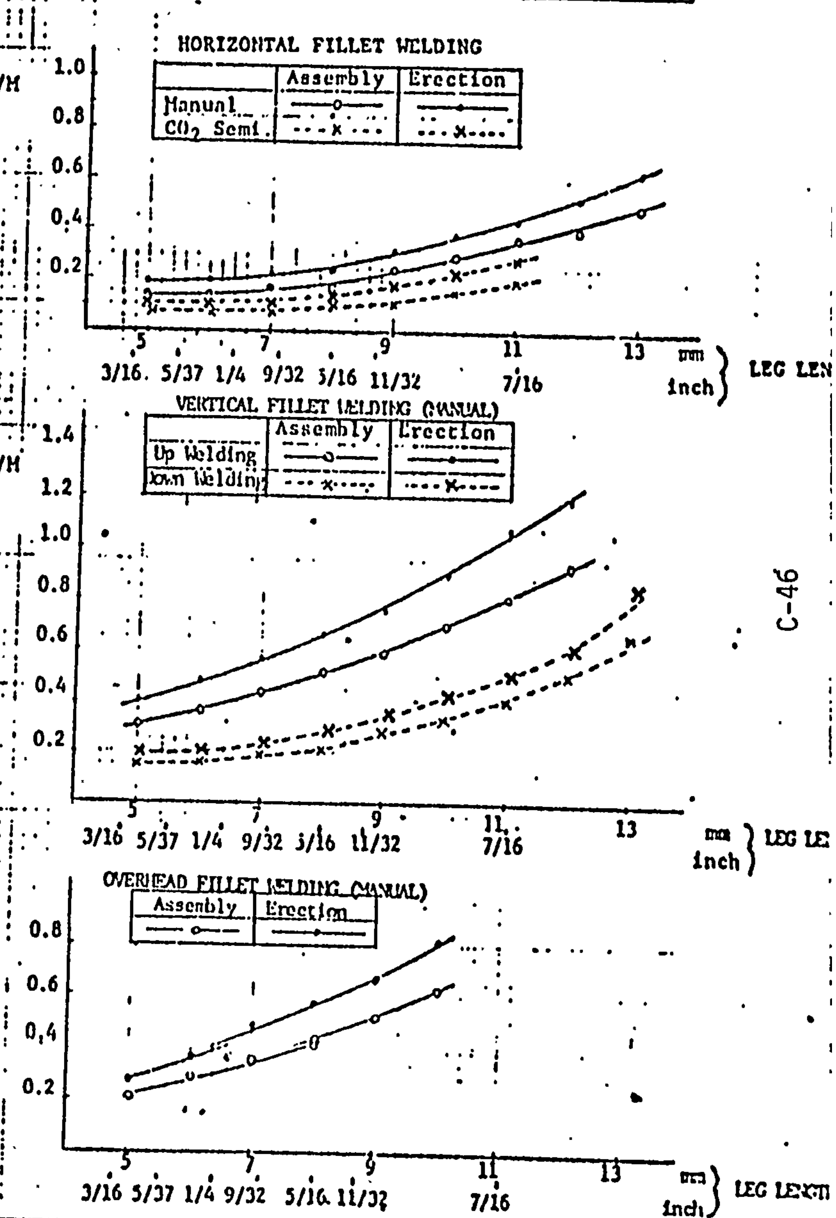


TABLE 3: WELDING LENGTH RATIO BY POSITION (In Japan)

JOINT	STAGE	WELDING LENGTH (%)	% WELDING LENGTH OF WELDING POSITION			
			FLAT	VERTICAL	HORIZONTAL	OVERHEAD
BUTT	Sub-Assembly	2.1%	1.9%	0.2%		
	Assembly	7.4	6.1	0.9	0.1%	0.3%
	Erection	5.7	1.4	2.1	1.0	1.2
	Sub-Total	15.2	9.4	3.2	1.1	1.5
FILLET	Sub-Assembly	31.7	30.1	1.6		
	Assembly	43.0	26.0	15.0		2.0
	Erection	10.1	5.1	3.0		2.0
	Sub-Total	84.8	61.2	19.6		4.0
TOTAL		100%	70.6%	22.8%	1.1%	5.5%

C-47

TABLE 4 EACH SIDE SUBMERGED ARC WELDING (SINGLE) IHI CONDITIONS

PLATE THICKNESS INCH	PLATE THICKNESS mm	EDGE PREPARATION	BACKING PASS A	BACKING PASS V	BACKING PASS IPM (CPM)	FINISHING PASS A	FINISHING PASS V	FINISHING PASS IPM (CPM)
1/4	6		530	34	19.7 (50)	750	34	25.6 (65)
9/32	7		580	34	19.7 (50)	800	34	25.6 (65)
5/16	8		620	34	19.7 (50)	850	34	24.8 (63)
11/32 3/8	9		650	34	19.7 (50)	880	34	24.8 (63)
13/32	10		680	34	19.7 (50)	900	35	23.6 (60)
7/16	11		700	34	20.5 (52)	920	35	22.8 (58)
15/32	12		730	34	21 (53)	950	35	21.7 (55)

ROD US-43 . 4.8 DIA. FLUX PFH-45

PLATE THICKNESS INCH	PLATE THICKNESS mm	EDGE PREPARATION	BACKING PASS A	BACKING PASS V	BACKING PASS IPM (CPM)	FINISHING PASS A	FINISHING PASS V	FINISHING PASS IPM (CPM)
13/32	10		720	33	21.7 (55)	900	38	23.6 (60)
7/16	11		760	33	21.7 (55)	920	38	22.8 (58)
15/32	12		800	33	21.7 (55)	940	38	22 (56)
1/2	13		830	33	21.7 (55)	950	38	21.3 (54)
17/32 9/16	14	70° 5 9	800	32	17.7 (45)	930	38	19.7 (50)
19/32	15	70° 6 9	830	32	17 (43)	950	39	18.5 (47)
5/8	16	70° 7 9	870	32	15.7 (40)	980	39	17.7 (45)
21/32	17	70° 8 9	900	32	14.6 (37)	1020	39	17 (43)
23/32	18	70° 6 6 6 90°	820	32	14.6 (37)	1100	36	14.2 (36)
3/4	19	70° 6 6 7 90°	820	32	14.6 (37)	1100	36	13.8 (35)

ROD US-43 6.4 DIA. FLUX PFH-45 B PASS

TABLE 5 IHI CONDITIONS

SINGLE → ← TANDEM

PLATE THICKNESS INCH	PLATE THICKNESS M/M	EDGE PREPARATION	BACKING PASS A	BACKING PASS V	BACKING PASS IPM (CPM)	FINISHING PASS A	FINISHING PASS V	FINISHING PASS IPM (CPM)
25/32	20	6, 6, 8; 70°, 90°	830	32	13.8	1100	36	12.6
7/8	22	7, 7, 8; 70°, 90°	880	32	13	1130	37	11.8
15/16	24	7, 7, 10; 70°, 90°	950	32	12.6	1200	37	10.2
1	25.4	9, 7, 9.4; 70°, 90°	960	32	11.8	1200	37	10.2
1 3/32	28	10, 9, 9; 70°, 90°	1050	33	10.6	1300	38	9.8
1 3/16	30	10, 9, 11; 70°, 90°	1100	34	10.6	1400	38	9
1 3/8	35	12, 11, 12; 70°, 90°	1150	34	9	1400	38	7.9

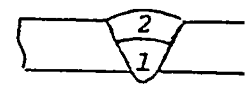
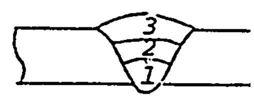
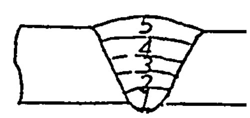
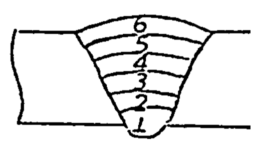
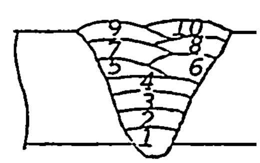
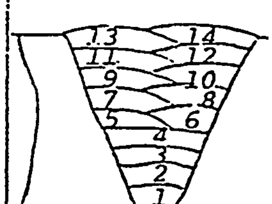
ROD US-43 6.4 Dia. FLUX PFH-45 B. PASS
KW-43 KB-14 F.PASS

PLATE THICKNESS INCH	PLATE THICKNESS M/M	EDGE PREPARATION		BACKING PASS A	BACKING PASS V	BACKING PASS IPM (CPM)	FINISHING PASS A	FINISHING PASS V	FINISHING PASS IPM (CPM)
13/32	10		L	600	32	31.5	750	32	31.5
7/16			T	600	36	(80)	750	38	(80)
15/32	12		L	650	32	31.5	800	33	29.5
			T	650	36	(80)	800	38	(75)
17/32 9/16	14	70°; 5, 9	L	750	32	27.6	900	34	29.5
			T	750	36	(70)	900	38	(75)
5/8	16	70°; 7, 9	L	850	32	25.6	1000	35	28.7
			T	850	36	(65)	1000	38	(73)
23/32	18	70°; 6, 6, 6; 90°	L	700	32	27.6	1000	33	27.6
			T	700	36	(70)	1000	38	(70)
25/32	20	70°; 6, 6, 8; 90°	L	720	32	26.8	1050	33	25.6
			T	720	36	(68)	1050	38	(65)
15/16	24	70°; 7, 7, 10; 90°	L	800	32	24.4	1100	34	20.9
			T	800	36	(62)	1100	38	(53)
1 3/32	28	70°; 10, 9, 9; 90°	L	900	32	19.7	1150	32	18.9
			T	900	36	(50)	1150	38	(48)
1 1/4	32	70°; 10, 9, 13; 90°	L	950	32	18.9	1200	32	15
			T	950	36	(48)	1200	40	(38)

ROD US-43 L:48 DIA. FLUX PFH-45 B. PASS

CO_2 ONE-SIDED SEMI-AUTOMATIC WELDING

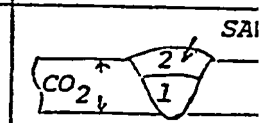
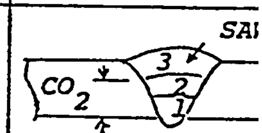
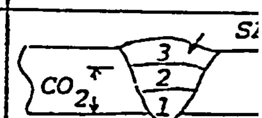
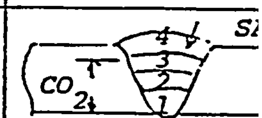
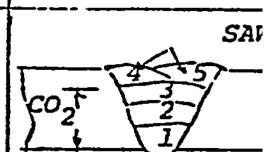
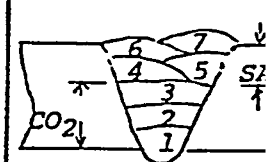
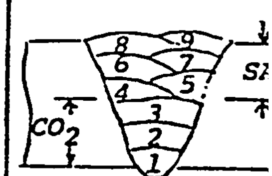
(Flat Position 50° V-Groove of Mild Steel)

PLATE THICKNESS		PASS	CURRENT (A)			VOLTAGE (V)			BUILD-UP SEQUENCE
inch	mm		Gap.0	Gap.3	Gap.6	Gap.0	Gap.3	Gap.6	
3/8	10	1	400	280	280	36	26	26	
13/32		2	350	330	330	34	33	33	
19/32	15	1	400	280	280	36	26	26	
		2∼3	360	340	340	35	35	35	
25/32	20	1	400	300	300	36	27	27	
		2∼5	400	370	370	37	36	36	
1	25	1	400	300	300	36	27	27	
		2∼6	400	370	370	37	36	36	
1 3/16	30	1	400	300	300	36	27	27	
		2	400	370	370	37	35	35	
		3∼10	400	400	400	38	38	38	
1 3/8	35	1	400	300	300	36	27	27	
		2	400	370	370	37	35	35	
		3∼14	400	400	400	38	38	38	

Rod Dia.: 1.6$^{\phi}$

COMBINED CO_2 ONE-SIDE AND SUBMERGED ARC WELDING (SINGLE MACHINE)

(Flat Position 50V-Groove of Mild Steel, gap 3~5mm)

PLATE THICKNESS		PASS	CO_2 ONE-SIDE		SUBMERGED ARC WELDING			BUILD-UP SEQUENCE
inch	mm		A	V	A	V	cm/min.	
1/2	13	1 2	300	27	550	35	24	
19/32	15	1 2 3	300 370	27 35	650	35	23	
23/32	18	1 2 3	300 370	27 35	800	34	22	
25/32	20	1 2 3 4	300 370 400	27 35 37	850	34	22	
7/8	22	1 2 3 4 5	300 370 400	27 35 37	900 900	33 35	30 26	
1	25	1 2 3 4 5 7	300 370 400	27 35 37	850 ~ 950	33 ~ 36	30 ~ 26	
1 3/16	30	1 2 3 4 5 9	300 370 400	27 35 37	850 ~ 950	33 ~ 36	30 ~ 26	

Rod: US 43 - 4.8φ

Flux: PFH - 45

Ref. No. HP-085

MEMOMNDUM

MAY 1, 1979

TO: JOHN LABORDE/LLOYD DELK

FROM: T. YAMAMOTO

SUBJECT : WELDING METHOD IMPROVEMENT

Through observation of the actual production field and this discussion with welding engineering, we found out several significant differences between LSCo's practice and IHI's practice for welding. Basically in IHI, the following will be taken into consideration:

1. The quality of hull steel depends on the quality of welding joints.
2. Welding joint quality depends on the edge condition.
3. The welding productivity of joint depends on the welding position. (i.e. flat position instead of overhead position; refer to attached tables).
4. The welding productivity. of joint depends on the work stage (i.e. assembly stage instead of erection stage; refer to attached figures).

From the above basic consideration, the following approach will be proposed to improve the welding method:

1 st Step

(1) On erection stage, overhead welding is to be minimized as much as possible.
i.e. Butt and seam joints of tank top plate.
Butt and seam joints of upper deck plates etc.

(2) For manual welding joints on assembly stage, edge preparation is to be finished on material preparation stage.
i.e. Internal joints of bilge plate.
Joint of girder plate, etc.

2nd Step

For manual welding joints on erection stage, edge preparation for plate is to be finished with machine cutting on assembly stage under the results of accuracy control activity and also for internal structures to be finished on material preparation stage.

For the 1st step, the cost variance will be easily confirmed under laboratory testing; for the 2nd step, under accuracy control activity, it is timely to decide the welding shrinkage amount and cut off the additional material prior to erection.

We will appreciate your consideration of the above proposals.

11t
Attachments

CC: Clyde LaRue
George Solomon
Gene Mayer
George Istre

Ref. No. HP-082

April 23, 1979

WELDING APPLICATION FOR SHIPBUILDING

Basic idea on welding application:

1. To make edge preparation down hand welding bevel angle as much as possible.

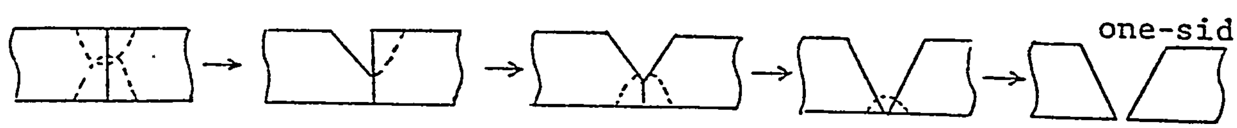
   Reasons:
   1) Quality becomes stable
   2) It is possible to make easy work position
   3) Rate of deposition is large

2. To reduce deposited metal as much as possible.

   Example: Change of groove angles; $60^{o}V \longrightarrow 50^{o}V$

   Various mechanical tests, approval test and accuracy control, etc., are necessary for application

3. To reduce gouging quantity *as* much as possible.

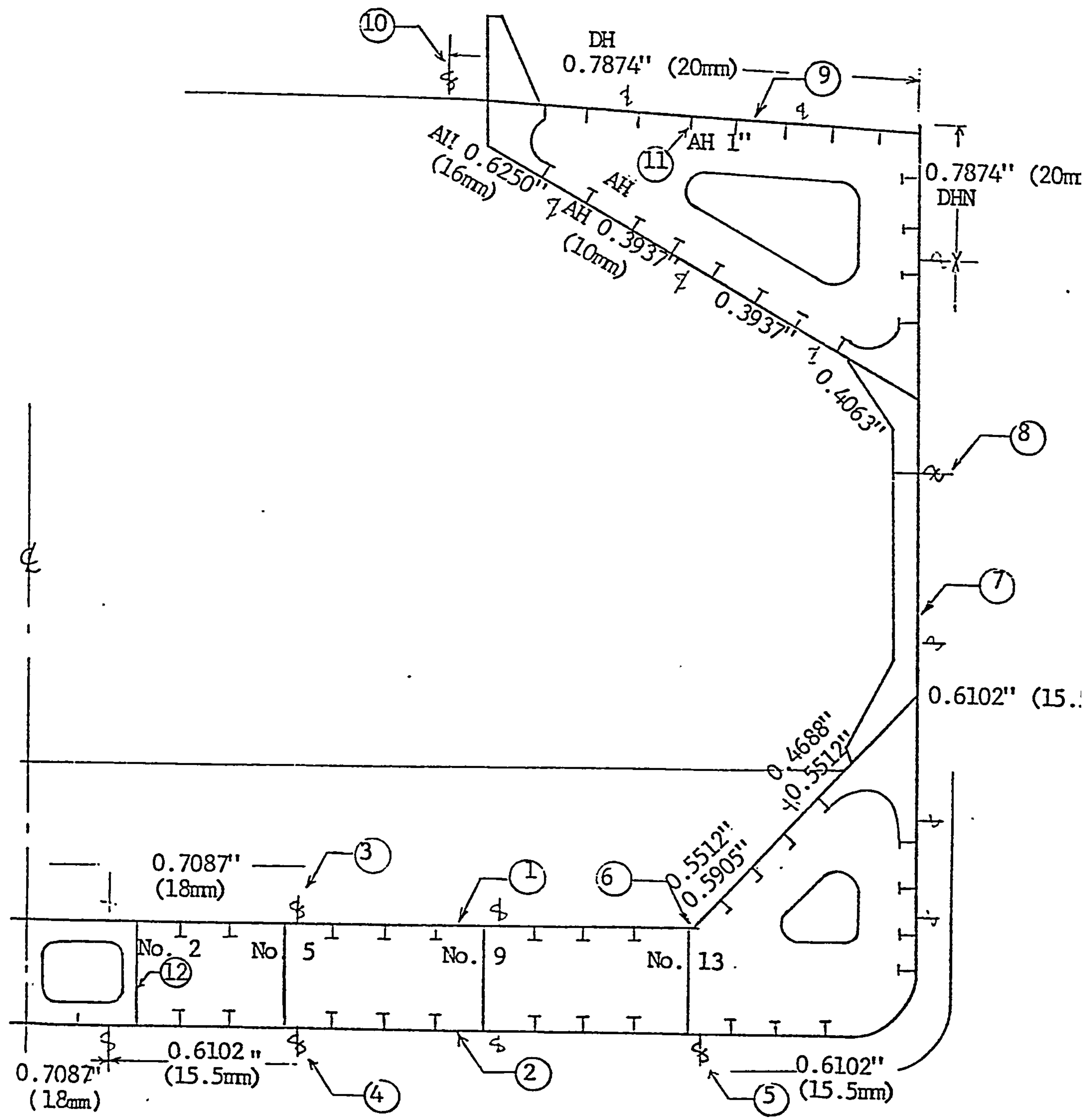


4. To reduce work steps by automation *as* much *as* possible.

   Notice: The premise conditions on which above item should be down are as follows:

   1) Edge preparation to be finished on prior stage by machine as much as possible
   2) Accuracy for unit to be improved under accuracy control activities

ERECTION STAGE



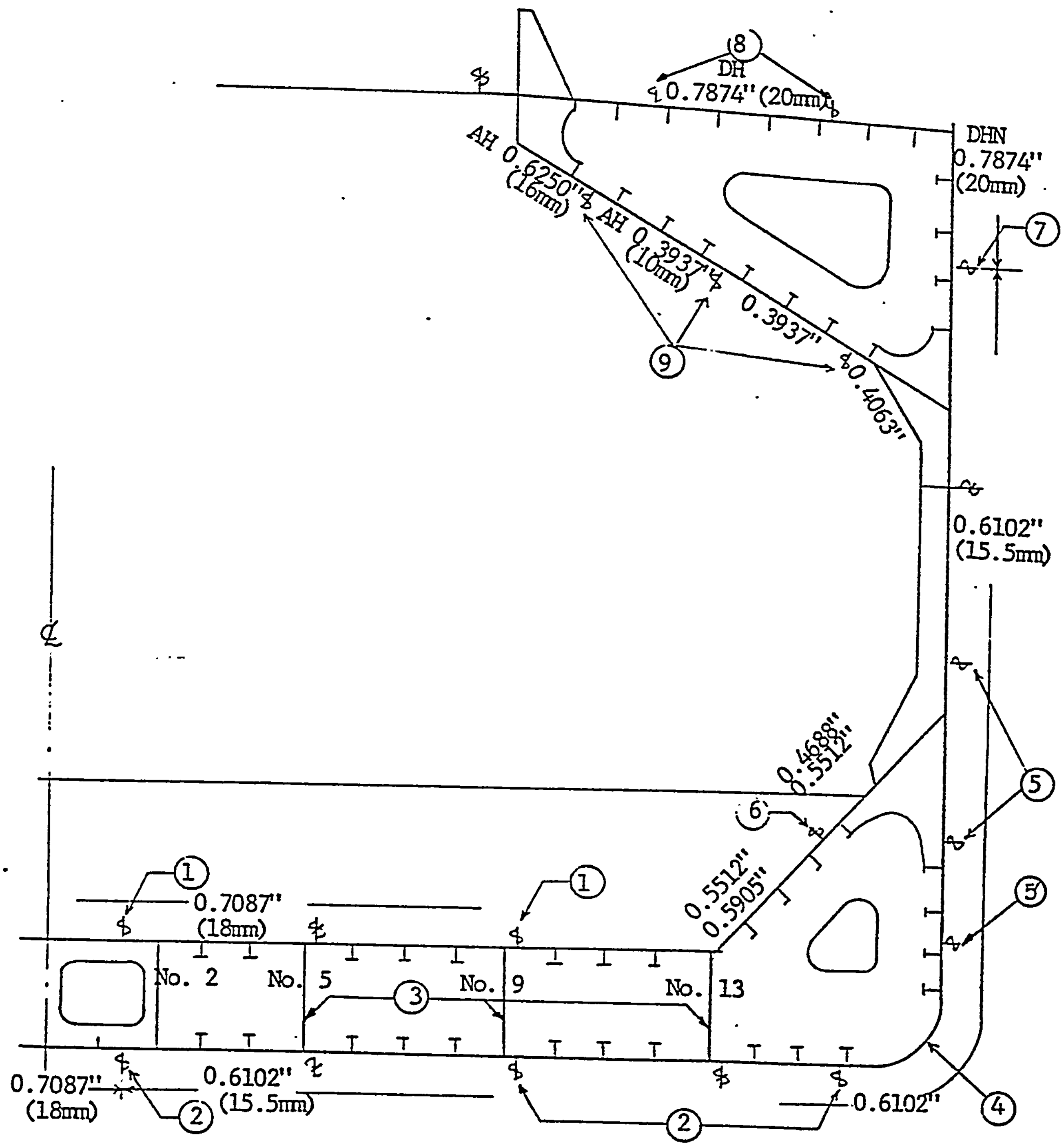
MIDSHIP SECTION

HP - 05a
APRIL 19 1979

WELDING APPLICATION FOR SHIPBUILDING - (1) ERECTION STAGE

				CURRENT METHOD			IMPROVEMENT - (1)			IMPROVEMENT - (2)		
JOINTS		THICKNESS	SYMBOL	EDGE PREPARATION	WELDING METHOD & BUILD UP SEQUENCE	HOUR/METER	EDGE PREPARATION	WELDING METHOD & BUILD UP SEQUENCE	HOUR/METER	EDGE PREPARATION	WELDING METHOD	HOUR/METER
①	BUTT OF T.TOP	0.7087" (18 mm)	B2V.1	60°	① TORCH or GOUGE ② MANUAL ③ GOUGE ④ SUBMERGED	[illegible] 3.0	50°, 2	① MANUAL ② SUBMERGED ③ GOUGE ④ MANUAL	[illegible] 2.1	50°, 4	CO2 ONE SIDE	1.4
②⑤	BUTT OF BOTTOM	0.7087", 0.6102"	"	60°	① TORCH or GOUGE ② MANUAL ③ GOUGE ④ MANUAL (OVER HEAD)	0.7087" 3.0 0.6102" 2.7	"	① MANUAL ② GOUGE ③ MANUAL	2.3 2.1	—	—	—
③	SEAM OF T TOP	0.7087"	"	60°	① MANUAL ② GOUGE ③ SUBMERGED	2.7	"	SAME TO ①	2.1	"	SAME TO ①	1.4
④	SEAM OF BOTTOM	0.6102" (15.5 mm)	"	60°		2.4	"	SAME TO ②	2.1	—	—	—
⑥	T.TOP " HOPPER SLOP	0.7087" × 0.5905"		① 50° ②	① MANUAL ② "	① 0.9 ② 0.2	50°	① FCAW ② MANUAL	0.7 0.2	—	—	—
⑦	BUTT OF S.SHELL	0.6102" (15.5 mm)	B2S4	60°, 60°	(1) GOUGE (2) MANUAL (3) GOUGE (4) MANUAL	3.5	50°, 2	① MANUAL ② GOUGE ③ MANUAL	3 2	20°, 14	ELECTRO-GAS EXCEPT UPPER S.Shell	1.7
⑧	SEAM OF S.SHELL	"	B2S4	60°, 60°	"	3.0	1/2 T, 35°, 15°	"	2.5	1/4 T	CO2 ONE SIDE	1.9
⑨	BUTT OF U.DECK	0.7874" (20 mm)	B2S4	60°, 60°	① TOUCH or GOUGE ② MANUAL ③ GOUGE ④ MANUAL	3.1	50°, 2	"	2.5	50°, 2	SUBMERGED MANUAL	2 4
⑩	SEAM OF U.DECK	0.4331" (11 mm)	B2S4	"	"	2.0	"	"	1.6	"	CO2 ONE SIDE	0.9
⑪	BUTT OF OBLONGL	1"	B2V.1	60°	① TOUCH or GOUGE ② MANUAL ③ GOUGE ④ MANUAL	5.8	"	"	5.5	24	CES FITTING HOUR INCLUDE	5.0
⑫	BUTT OF GIRDER	0.5512" (14 mm)	B2S4	60°, 60°	① GOUGE ② MANUAL ③ GOUGE ④ MANUAL	3.2	"	SAME TO ⑦	2.9	—	—	—

ASSEMBLY STAGE



MIDSHIP SECTION

WELDING APPLICATION FOR SHIPBUILDING - (2) ASSEMBLY STAGE

			CURRENT METHOD				IMPROVEMENT - (1)			IMPROVEMENT - (2)			21.3
JOINTS		THICKNESS	SYMBOL	EDGE PREPARATION	WELDING METHOD, BUILD UP SEQUENCE	HOUR/METER	EDGE PREPARATION	WELDING METHOD, BUILD UP SEQUENCE	HOUR/METER	EDGE PREPARATION	WELDING METHOD	HOUR/METER	H/M
①	SEAM OF T.TOP	0.7037" (18mm)	B2V2	45° 3/16	① SUBMERGED ② GOUGE ③ SUBMERGED	0.72	30° 3/32	① SUBMERGED ② GOUGE ③ SUBMERGED	0.64	50°		0.47	0.35
②	SEAM OF BOTTOM	0.6102" (15.5mm)	B25.5		① GRINDING ② SUBMERGED ③ GOUGE ④ SUBMERGED	0.63	"	SAME TO ①	0.57	—	—	-	0.31
③	BUTT OF SIDE GIRDER	13/32" × 3/8" × 11/16" (12mm) × 3/4	B25.4		① GOUGE ② MANUAL ③ GOUGE ④ MANUAL VERTICAL POSITION	2.7	30°	"	0.48				0.27
④	BUTT OF BILGE	0.6102" (15.5mm)	B25.4		" VERTICAL AND FLAT POSITION	3.2	50°	① MANUAL ② GOUGE ③ MANUAL	3.0	—	—	—	
⑤	SEAM OF SIDE SHELL	"	B25.6	"	SAME AS ②	0.63	50° 3/32	SAME AS ①	0.57	—	—	—	0.31
⑥	SEAM OF HOPPER SLOPE	[illegible] (12mm) [illegible] (14mm)	"		"	0.56 0.58	50°	"	0.48 0.51	—	—	—	0.27 0.29
⑦	SEAM OF SIDE SHELL	0.6102 " × 0.7874	"		"	0.63	50°	"	0.57	—	—	—	0.29
⑧	SEAM OF UPPER DECK	0.7874" (20mm)	B2V2	45° 3/16	SAME AS ①	0.73	50° 3/16	"	0.67	50°	SAME TO ①	0.42	0.32
⑨	SEAM OF TOP SIDE TANK	0.3937" (10mm) × 0.4063" × 0.6230"	B255		SAME AS ②	0.35	—	—	—	—	—	—	0.27
⑤'	SEAM OF SIDE SHELL	0.6102" (15.5mm)	B25A		① GOUGE ② MANUAL ③ GOUGE ④ MANUAL	2.8	35° 15°	① MANUAL ② GOUGE ③ MANUL	2.6	—	—	—	

APPENDIX D

PIPE FABRICATION:

LIST OF EQUIPMENT AND EXPLANATION OF

PICTURES OF EQUIPMENT

EXISTING FACILITY OF
AIOI'S PIPE SHOP IN IHI

EQUIPMENT NAME	SPECIFICATION (Min.)	(Max)	QUANTITY
Pipe Bender - Type 2	1/2"	2" (Sch 40)	1
Pipe Bender -Type 4	1"	4" (Sch 20)	1
N.C. Pipe Bender - Type 4	1"	4" (Sch 20)	1
Pipe Bender -Type 8	3"	8" (Sch 20)	2
N. C. 4 point Assemble Machine	1/2"	2-1/2"	1
N. C. 4 Point Weld Machine	1/2"	2-1/2",	1
N. C. 2 Point Assemble & Weld Machine	1/2"	2-1/2"	1
Automatic Pipe Racker	1/2"	2-1/2"	1
Digital cutting Machine	1/2"	2-1/2"	1
Grinding Cutter	Full	4"	2
Pipe Coaster - Model NPC-108 E	1"	8"	1
Pipe Coaster - Model NPC-112 E	2"	12"	1
Gas. Cutting Machine	3"	32"	1
O CO_2 - Gas Shield Arc Welding Machine		(Capacity)	28
CO_2 - Gas Shield Arc Welding Machine		500A	5
D. C. Tungsten Inert-Gas Welding Machine		200A	4
D. C. Tungsten Inert-Gas Welding Machine		500A	1
A. C. shield Metal Arc Welding Machine		200A	7

A.C. Shield Metal Machine			4
A. C.Shield Metal Arc Welding.	400A		6
A. C. Shield Metal Arc Welding Machine	500A		10
	(Main)	(Aux.)	
Over Head Crane	20 Ton	10 Ton	1
Over Head Crane	10 Ton	5 Ton	1
Over Head Crane .	3 Ton	Nothing	1
Tower Crane	½ Ton	Nothing	1
Tower Crane	½ Ton	Nothing	1
Wall Crane	2 Ton	Nothing	2
Wall Crane	1 Ton	Nothing	4
Wall Crane .	2.5 Ton	Nothing	1
Gantry crane	5 Ton	Nothing	2
Gantry Crane	2.5 Ton	Nothing	1
Crane Car	4.5 Ton	Nothing	1
	(Length x Width)		
Fitting Slab	5Ft. x5 Ft.		30.
Pallet *(for* shipments pipe)	15 Ft. X 5 Ft.		250
Pallet (for shipments piece)	3.3 Ft. X 3 Ft.		40
Lath (Beveling Machine)			2

(a) 1 ton - Wall Crane

(b) Press roller for manual weld

(c) Pipe coaster (Saddle branch cutter)

(d) Gas cutting machine

(e) Straight pipe fabrication jig.

(f) Automatic CO_2 gas shield weld machine

(g) Welding table with turning saddle

In the above, (d), (e) and (f) are required for the straight pipe fabrication rack in your-planned new pipe shop, refer to PF-23, dated April 3, 1979.

Furthermore, as your production quantity would be required much more in the future than at present, some NC machines would be required.

II. EXPLANATION OF THE PICTURES

1.

Automatical raw pipe (½"∿2½") storage rack with digital cutting machine.

A. Loading System

Store raw pipes on racks by diameter and schedule.

B. Unloading System

A-pipe being cut is picked up, one by one:

C. Cutting System

Picked-up pipe is cut according to numerical data.

Every activity described in the above is done automatically.

D. Capacity

Storage capacity: 63-2 tons

Dead Weight: 31-0 tons

2. NC Assemble and 2-Point Weld Machine

Assemble fittings and cut pipes supplied by "Digital Cutting .Machine", and weld. This is controlled numerically.

A. Assembling Stage consists of the following:

(a) Pipe robot
(b) Flange robot
(c) Flange bolt hole detector (FHD)
(d) Flange checking machine (CM)

B. Welding System consists of the following:

(a) Welding torch #1 and #2
(b) Turntable

C. Capacity

- **Pipe dia. : ½"~2½"**
- **Pipe length: 6"~3' 3"**

3. NC Assemble Machine

Assemble fittings and cut pipes perform tack welding.

A. <u>Assembling System</u> consists of the following:

(a) Flange robot
(b) Flange bolt hole detector (FHD)
(c) Flange checking machine (CM)

B. Capacity

Pipe dia. : ½"~2½"

Pipe length : 3'3 13/32"~18'

4. NC 4-Point Weld Machine

Weld assembled pipes by "NC Assemble Machine." Weld 4 points at the same time.

5. NC Pipe Bender -- Type 4

Bend pipes (1"~2½") after assembly and weld
Bending angle, bending start points, turning angle and etc. are controlled.

A. Specially Equipped Mechanism

(a) Check device
Check flange to set bending start points and turning angle.

(b) Flange bolt hole detector (FHD)

B. Capacity

Pipe dia. : 1"~ 4" (Sch. 20)

Pipe length : 1' 7 11/16" ~18'

6. Straight Pipe Fabrication Jig (for small pipes)

   Set fittings distance on both sides of a pipe. Manual tack welding

   A. The jig consists of the following elements:

      (a) Flange setting plate (Fixed side)

      (b) Flange setting plate (Moving side)

      (c) Moving rack for pipe supporting

   B. Capacity

      Pipe dia. : ½"~2½"

      Pipe length : 3′ 3 13/32"~18′

7. 7.1 ton - Wall Crane

   A. Capacity

      (a) Max. load : 1 ton

      (b) Max. Height : 20′

      (c) Max. Reach : 32′ 9 11/16″

8. Press Roller for Manual Weld

   Rotate pipes for manual welding. Pressed rollers are equipped to rotate curved pipes.

   A. Capacity

      Pipe dia. : ½″~8″

9. Pipe coaster

   Cut saddle branch pipes automatically. (maker’s catalog is attached)

10. Gas Cutting Machine

Cut pipes by *gas* turning on roller. Beveling ossible.

A. Capacity

Pipe dia. : 3"~32"

Pipe length : Max. 20'

11. Straight Pipe Fabrication Jig for Big Pipes

A. Capacity

Pipe dia.

Pipe length : 3'~18'

12. Automatic CO_2 Shield Welding-Machine

Weld automatically 4 points at the same time. The pipe is rotated by the roller.

A. Capacity

Pipe dia. : 3"~24"

Pipe length : 3'~20'

13. Welding Cable with Turning Saddle

Fix a pipe and weld turning around the table.

A. Capacity

Pipe dia. : ½" ~ 8"

Pipe length: depends on shop

III. <u>RECOMMENDABLE EQUIPMENT TO LSCO</u>

Considering the scale of planned and existing pipe shop in Livingston, recommendable equipment is as follows:

(4) utilization of benders

As above mentioned (3-a,3-b), it is evident that the utilization of the benders is definitely effective for the pipe fabricationt However, some existing systems in the field of engineering and production are not suitable for the application of the bending system. Therefor following items have to be investigated:

(a) Drawing system for pipe fabrication.
(b) Pipe fabrication flow. (Including materials flow and delivering system for fabricated pipes.)
(c) Control system for pipe fabrication.
(d) Necessity of new benders, because type of existing benders are so old that it is hard ot keep high efficiency, high accuracy and easy operation.

Item (4-d) is a principal matter to establish an effective bending System. Please investigate item (4-d) as soon as possible. We will fully assist on these subjects.

ss/py

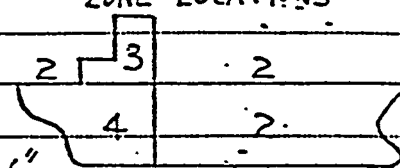
cc: Mr. Ed Paden
Mr. Joe wise
Mr. Ron McKenney
Mr. Frank Laudano

Ref.-1

QUANTITY OF PIPES

FROM DESIGN DATA OF IHI F-32

ZONE LOCATIONS



Exc. for PVC PIPE, and Cu PIPE less than 3/8"

STAGE	ZONE / QUANTITY	2	3	4 *	TOTAL
MODULE	THE NUMBER	432	—	1806	2238
	LENGTH - yds.	1314	—	3028	4342
	WEIGHT - lbs.	31445	—	94315	125760
ON-HULL UNIT	THE NUMBER	1235	717	2430	4382
	LENGTH - yds.	3619	1267	4994	9880
	WEIGHT - lbs.	138423	17044	116095	271562
ON-BOARD	THE NUMBER	205	355	714	1274
	LENGTH - yds.	217	347	1203	1767
	WEIGHT - lbs.	5159	6390	31013	42562
TOTAL	THE NUMBER	1872	1072	4950	7894
	LENGTH - yds.	5150	1614	9225	15989
	WEIGHT - lbs.	175027	23434	241423	439884

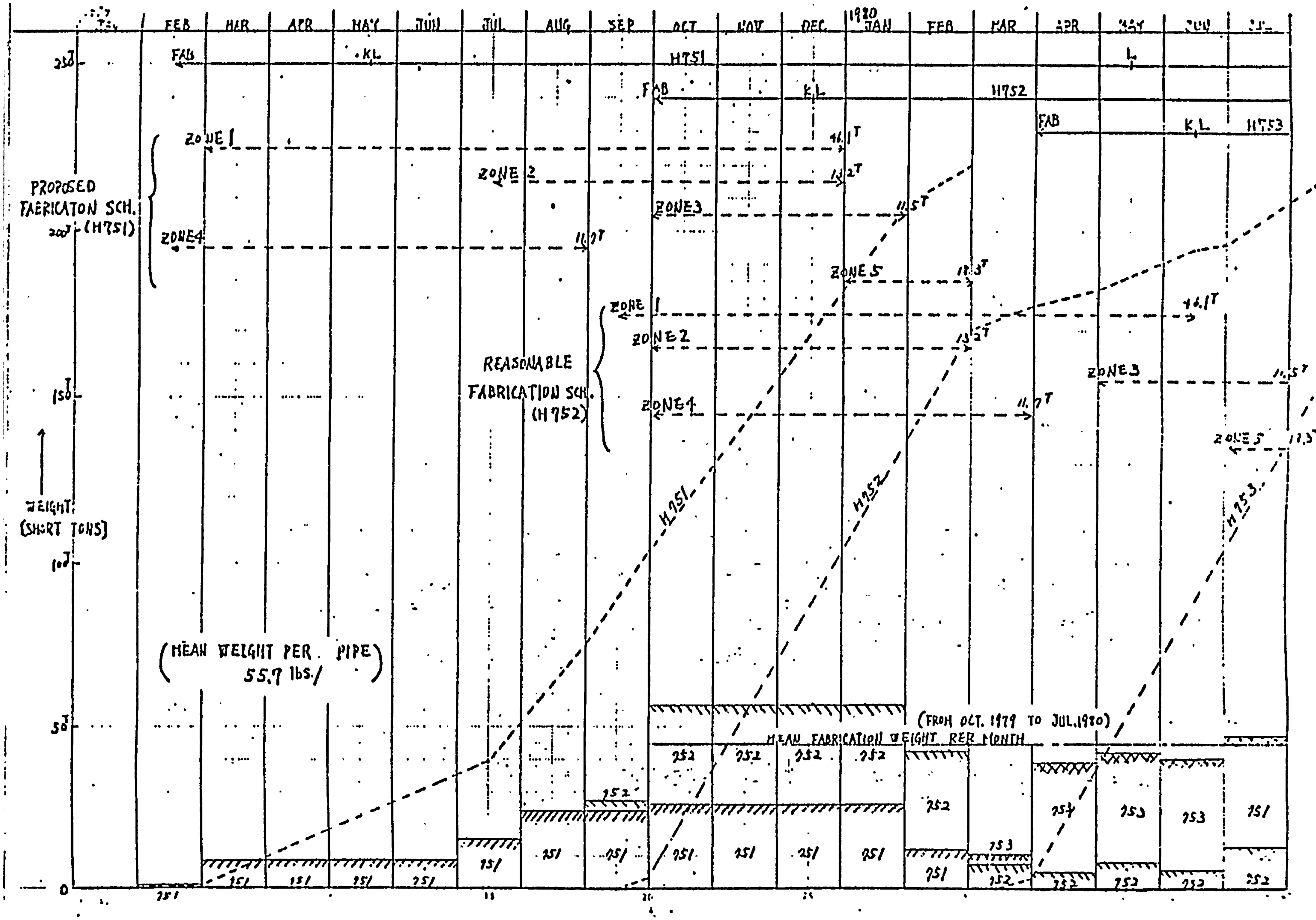
* The quantity in ZONE 4 represent 1.4 times as much as quantity of IHI F-32 by reason of the difference of specification between IHI's and LSCO's.

Ref.-2

ESTIMATION FOR LSCO F-32

CONVERSION FROM IHI DATA TO RESPECTIVE ZONE IN LSCO.

ZONE (LSCO)	CORRESPONDING ZONE (IHI)	UNIT	QUANTITY
1	ON-HULL UNIT of Z (x 4/6)	THE NUMBER	823
		LENGTH -yds.	2413
		WEIGHT -lbs.	92281
2	4& ON-HULL UNIT of Z (x 1/6)	THE NUMBER	5156
		LENGTH -yds.	9828
		WEIGHT -lbs.	264895
3	ON-HULL UNIT of Z (x 1/6)	THE NUMBER	206
		LENGTH -yds.	603
		WEIGHT -lbs.	23071
4	3	THE NUMBER	1072
		LENGTH -yds.	1614
		WEIGHT -lbs.	23434
5	MODULE of Z & ON-BOARD of Z	THE NUMBER	637
		LENGTH -yds.	1531
		WEIGHT -lbs.	36604
TOTAL		THE NUMBER	7894
		LENGTH -yds.	15989
		WEIGHT -lbs.	439884


FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1980 JAN FEB MAR APR MAY JUN JUL
FAB KL H751 L
FAB KL H752
FAB KL H753
PROPOSED FABRICATON SCH. (H751)
ZONE 1 46.1T
ZONE 2 13.2T
ZONE 3 11.5T
ZONE 4 11.7T
ZONE 5 13.3T
REASONABLE FABRICATION SCH. (H752)
WEIGHT (SHORT TONS)
250T
200T
150T
100T
50T
0
(MEAN WEIGHT PER PIPE 55.7 lbs.)
H751
H752
H753
(FROM OCT. 1979 TO JUL. 1980)
MEAN FABRICATION WEIGHT PER MONTH
751
752
753

Ref.-4

PIPES APPLICABLE BENDER

FROM DESIGN DATA OF IHI F-32

DIAMETER	THE NUMBER OF PIPES *	%
1/2"	578	16.0%
3/4"	43	1.2
1"	832	23.0
1 1/2"	730	20.1
2"	565	15.6
2 1/2"	257	7.1
3"	181	5.0
4	255	7.0
5	67	1.8
6	73	2.0
8	39	1.1
10	2	0.1
TOTAL	3622	100

(THE NUMBER OF ALL PIPES PER SHIP : 7894)

* The number of pipes is indicated as the summation of the number of every zone in a ship.

IHI MARINE TECHNOLOGY, INC.

Tel: (212) 267-5650
TWX: 710-581-2758
% George G. Sharp, Inc.

March *12,* 1979 .

Suite 1830
100 Church Street
New York, N Y. 10

Eiji Yamamoto
Ref. No. PF- 10

PROPOSAL

ATTENTION: Clyde LaRue

SUBJECT: Total Scope of Development for Pipe Shop

From our observation through the last three (3) weeks, we have found that your new Pipe Shop should be developed in accordance with the following procedure:

	Sub-Task #
(1) Productivity”	3-2
(2) Production Method	3-2
(3) Establishment of Capability of Each Stage	3-2 & 4-2
(4) Establishment for Each Stage Area	4-2
(5) Consideration of Pipe Shop's Lay-Out	4-2

Hereafter, this d&cription and schematical expression in detail is attached.

Therefore, since the sequence would be the base of our assistance, please investigate the application of the above items.

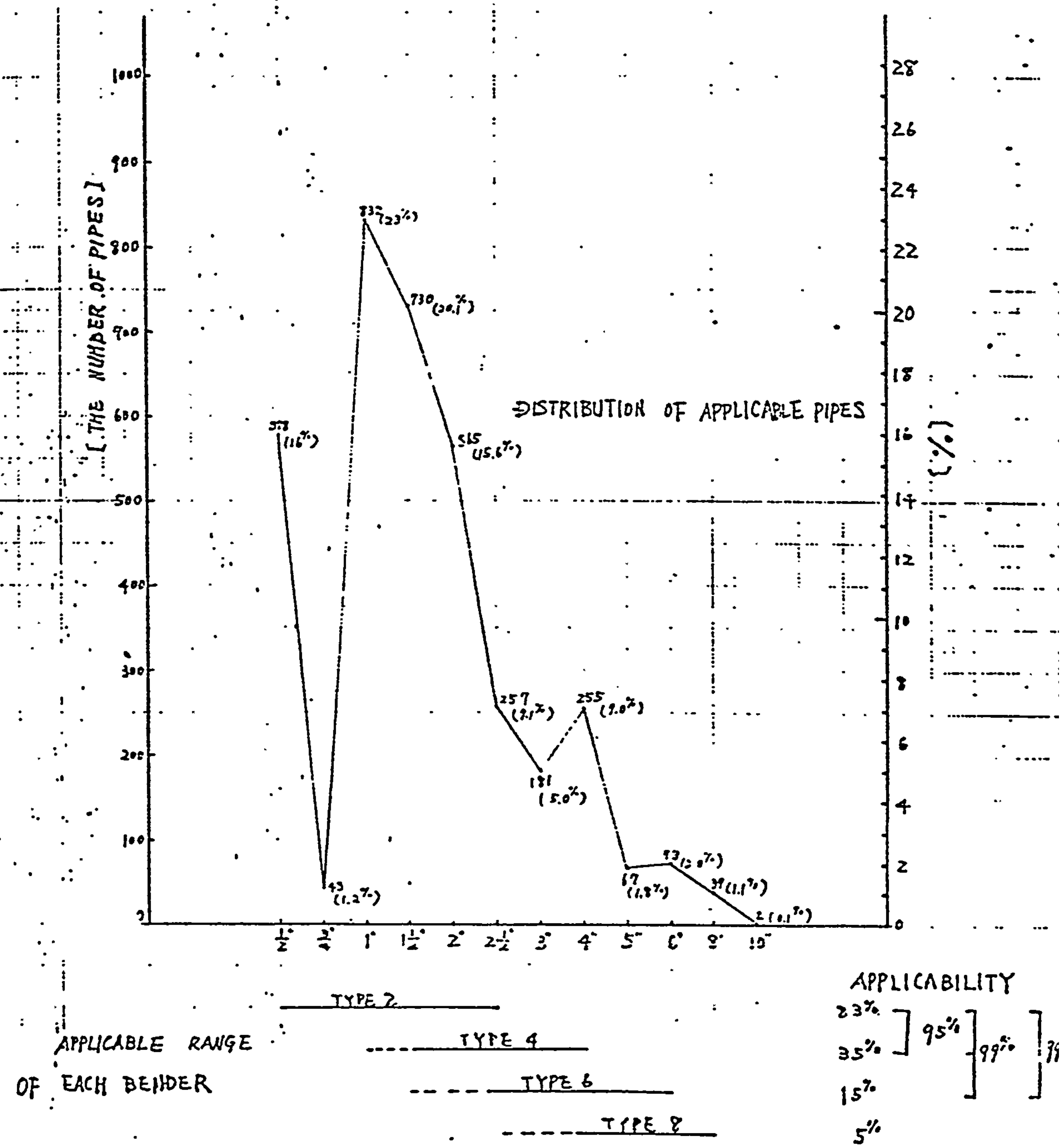
EY:bb

Attachment

CC: Ron McKenney
Ken kittrell

Ref.-5

APPLICABILITY OF BENDER



NOTE : Since the number of "TEMPLET PIPE" is not included in this tabel, the practical quantity of the applicable pipes will be more than above graph indicati

DEVELOPMENT PROCEDURE OF PIPE SHOP

**Presuppsition: Every development should be done considering the future modification towards an idealized shop.

I. Productivity

1.1 Establishment of the productivity target

(a) Quantity of Production: No./Day, W. T./Month

(b) Estimation of the work quantity in each stage

* cutting
* Bending
* Fabrication
* Welding
* Finishing
* Treatment
* Marshalling
* Material Handling

1.2 Design Base

Physical characteristics of manufactured pipes

i) Bulker

(a) Average number of lengths, each size.

(b) Average weight, each size.

(c) Maximum length, maximum weight.

ii) Other types of ships

(a), (b), and (C).- Same as the above mentioned.

iii) Future modifications for higher producibility

II. Production Method

2.1 Investigate the most suitable production method.

2.2 Consideration of suitable fabrication methods complying with physical characteristics:

(a) Storage Method

(b) Cutting Method

(c) Fabrication Method

(d) Welding

(e) Pickling

Etc.

2.3 Consideration of process control

(a) Process Control Sheet

(b) Pipe Cutting Plan

(c) Instruction Sheet for Connecting Sub-Assembly Units in Shop

(d) Instruction Sheet of Palletizing

2.4 Manufacturing Flow

(1) Concretely draw up the flowchart of the fabrication process

(a) Establishment of the main manufacturing flow

(b) Consideration of the effective fabrication sub-line

III. Establishment of Capability of Each Stage

3.1 Determine "bottlenecks" of stages of operation and consider improvements to maximize total efficiency.

1) Capability of each stage are decided in accordance with the conditions of the above mentioned"(l.l (b)".

Iv. Establishment for each stage area

(a). Facility Space

(b) working Space

(c) Buffer of Stage to Stage

(d) Aisle -Ways and overhead crane safety passageway

V. Consideration of Pipe Shop's Lay-Out

5.1 Flowing direction of overall Pipe Shop is decided by means of the sequence of operation in the Pipe Shop and exit of shipments manufactured.

5.2 Also, the entrance of fittings for pipe fabrication shall be decided.

5.3 They are established to apply to each stage area as in Item “4" above.

APPENDIX E

CONCEPT AND APPLICATION OF PRE-OUTFITTING

IHI MARINE TECHNOLOGY, INC.

TTP REPORT

TASK 3 PLANNING AND PRODUCTION CONTROL

TASK4 FACILITY AND INDUSTRIAL ENGINEERING

(OUTFITTING)

CONCEPT AND APPLICATION OF PREOUTFITTING

OCTOBER 1980

PREPARED BY

SHUJI SATO

IHI MARINE TECHNOLOGY, INC.

TABLE OF CONTENTS

I. Introduction (Overall view of total outfitting system)

I-1 Zone Outfitting

Over three decades ago, shipbuilders in Japan were obliged to make effort to shorten construction period according to demands of the shipping world.

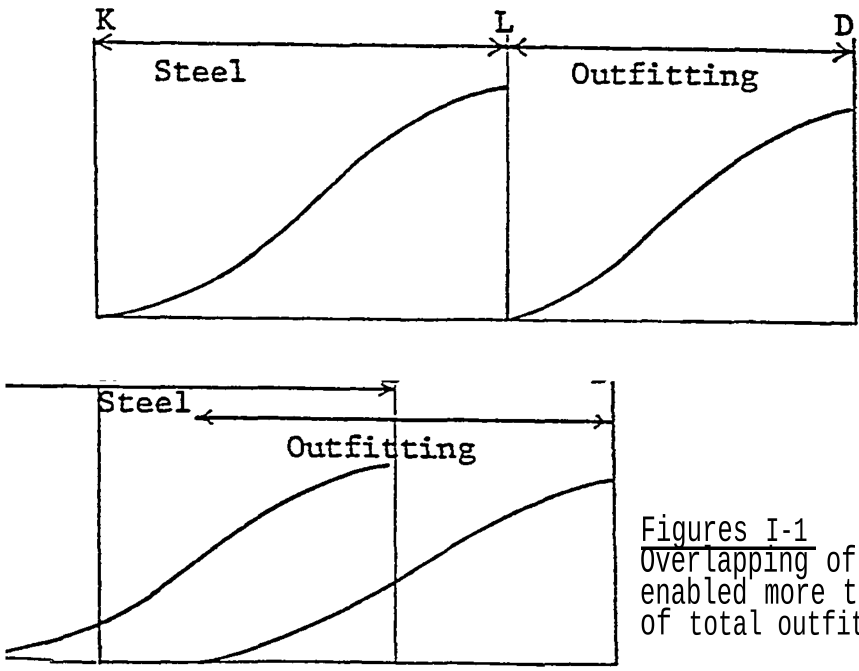
Consequently the above effort, which has been done very successfully, is also recognized to have produced such benefits as:

- improved safety
- reduced cost
- better quality
- adherence to schedule

The shortening required to improve conventional shipbuilding styte in both steel and outfitting areas. "Hull Block Construction Method" (HBCM) in the area of steel construction made a great contribution to the above, particularly it shortened the period between keet-lay and launching.

In the area of outfitting, on the other hand according to a demand of shortening the period between launching and delivery, concept of "Zone Outfitting" played the same role as HBCM. Conventional outfitting is implemented by functional system, and mostly done as areas of the ship become structurally complete thereby concentrating outfit craftsmen In confined spaces over relatively short periods, especially between launch and delivery. Under the above circumstances, therefore, the artifice of the shortening is nothing but increasing interference between crafts. The benefits mentioned in the above could not possibly be produced as consequence.

Contrarily, zone outfitting is an attempt to shorten total construction period through overlapping of steel and outfitting, illustrated in figure I-1, without interference between them.



Figures I-1
Overlapping of steel and outfitting enabled more than 50% completion of total outfitting as of launching.

The HBCM has a logic orienting zone-by-zone construction rather than system-by-system. Great part of construction work is shifted from erection site to shops being broken down into appropriate size of units which correspond to zone. In shops it is safer, cleaner, and tools and materials can be delivered to work sites quickly and economically. The shifting of work permits more freedom in applying a logic work break down structure to achieve more uniform production flow. Zone outfitting is a method developed under the same logic.as HBCM.

Zone outfitting which addresses everything within a limited 3-dimensional space. It frees outfitting as much as possible from dependence on steel construction progress and from arbitrary control as ships' systems. The zone approach permits and encourages most of the outfitting to be accomplished earlier and in shops or some places other than erection site. It is product oriented in that it ignores systems during the construction phase and instead, focuses on production of interim products. These, which are assemblies incorporating various pieces of systems, are then installed in the shortest time at the erection site. The result is not only shortening of building period but also safer work, reduced cost, better quality, and adherence to schedules. Fig. I-2 summarizes the goals and benefits of zone outfitting.

A zone might correspond to a compartment or even an integral part of a compartment such as a cargo hold or machinery space and their

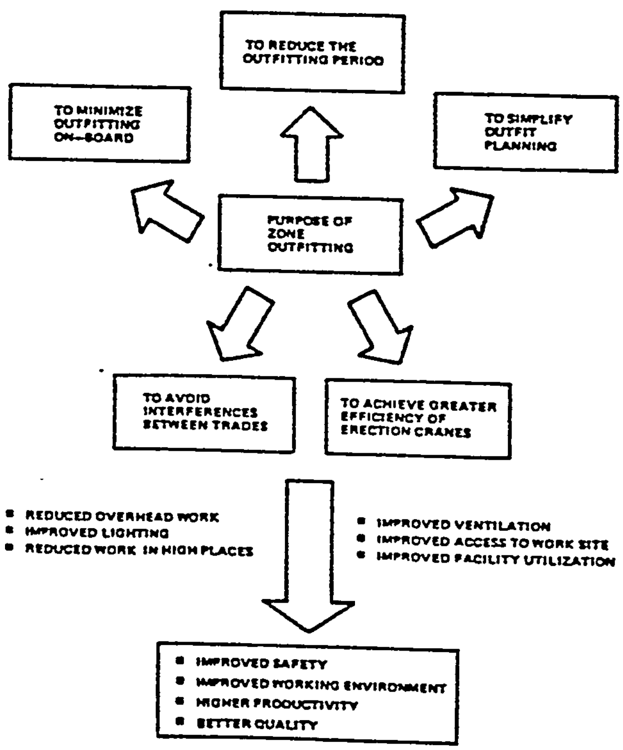


Figure I-2: Goals and Benefits of Zone Outfitting subdivisions. An entire structure, or just one of its levels, could be a zone even though a number of compartments are included. Also, a zone could encompass partial regions from two adjacent compartments even though separated by a bulkhead. Thus, a zone is any sub-division of the planned ship which best serves for organizing information needed to support" outfitting at a particular stage of construction. Zone outfitting features three basic stages: on-module, on-unit, and on-board. In this report, hereafter, on-module outfitting and on-unit are generically called "preoutfitting".

I-2 Preoutfitting

Preoutfitting can be categorized mostly into either on-module or on-unit outfitting.

On-module outfitting is the assembly of an interim product consisting of manufactured and purchased components. Modules which are interim products of on-module outfitting are categorized into the following groups.

I. Machinery Modules

Centering to the machinery, various kinds of material are compactly assembled together founded on machinery foundation.

ballast pump module
feed water pump module (figure I-3)
F.O. purifier module
etc.

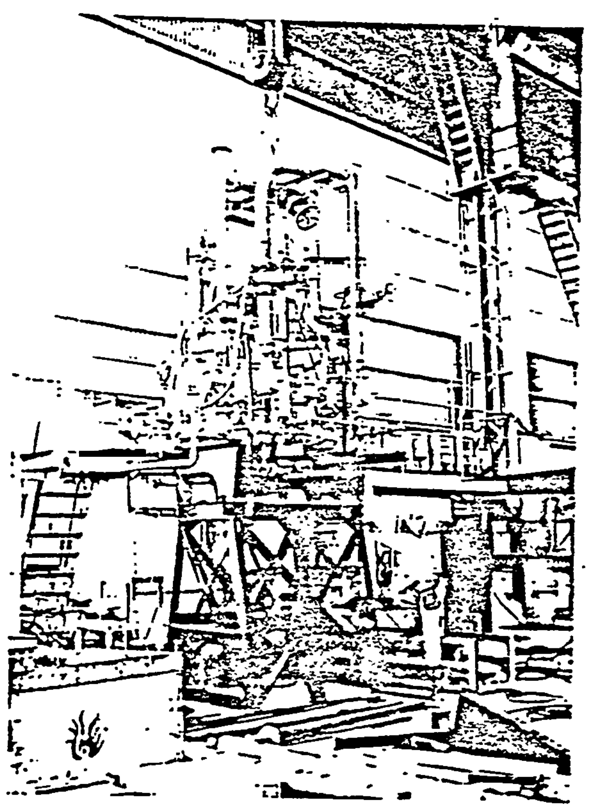


FIGURE I-3:

Feed water pump module

2. Geographical Modules

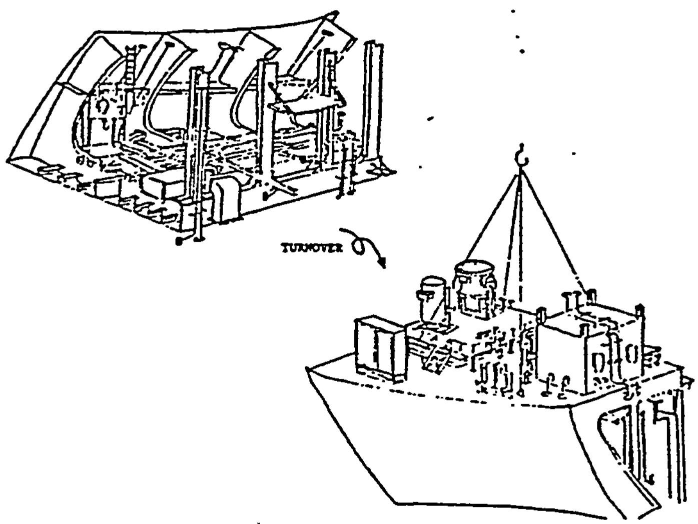
Consists of pipes, which are main structure of this type of module, walk ways, wire cable ways, and etc.

. pipe passage on deck module
. pipe passage on engine room unit
. etc.

3. Steel Combination Modules

Combination of module assembly and steel structure.

engine flat module (Figures I-4)
. tank module
. etc.
. etc.



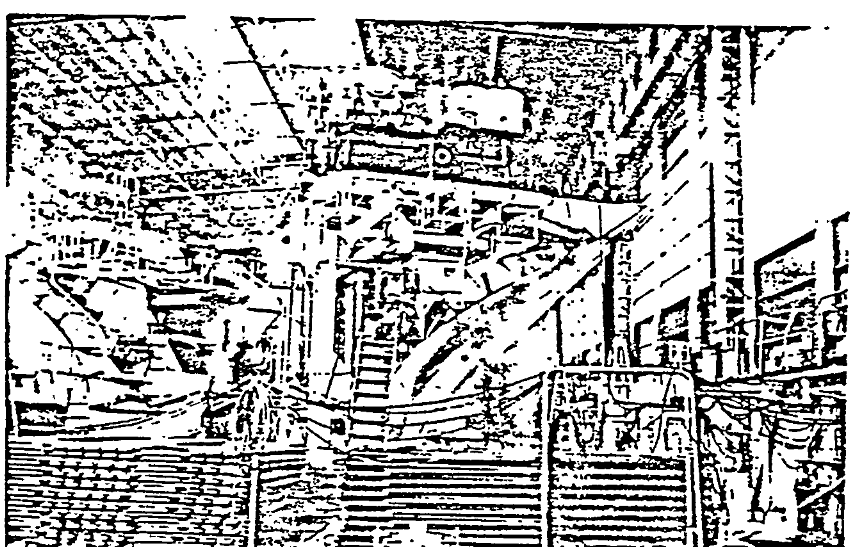
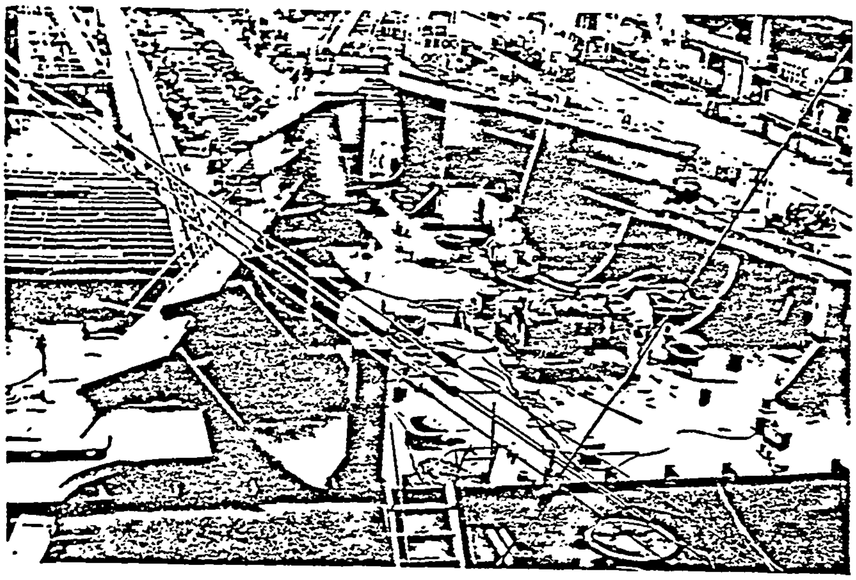


Figure I-4: Lower Engine Flat Module
(Steel combination modules)

As on-module outfitting can usually be done apart from steel construction, it is allowed to be performed in shops. Shop work provides ideal climate, lighting, access and equipment, and consequently increases the opportunity for improved safety, quality, and productivity. The above is the best advantage of on-module outfitting. Therefore on-module outfitting should be given the highest priority even though there is some impact on steel construction progress or even on hull design. One of the examples of hull design modification is illustrated in figure I-5.



Figures I-5:
Steel construction of inner-bottom tank top. (Engine room) Side shell and bulkhead are elevated 6′ to 10′ to avoid interference between modules and side shell web at side shell erection.

On-unit outfitting is the installation of outfit components onto a hull unit during its assembling and/or after its completion. It is the next alternative to on-module outfitting. On-unit outfitting may be done on a hull assembly slab, a unit may be moved to an inside or outside area designated for outfitting.

Though on-unit outfitting requires good coordination between steel outfitting and painting, it provides much better working circumstances, accessibility, and usability of equipments. Above all, on-unit outfitting on engine flat units produces great deal of benefit because of material concentration beneath flats and applicability of downward installation on units inverted with top side down. Figure I-6 illustrates on-unit outfitting on one of engine flat units.

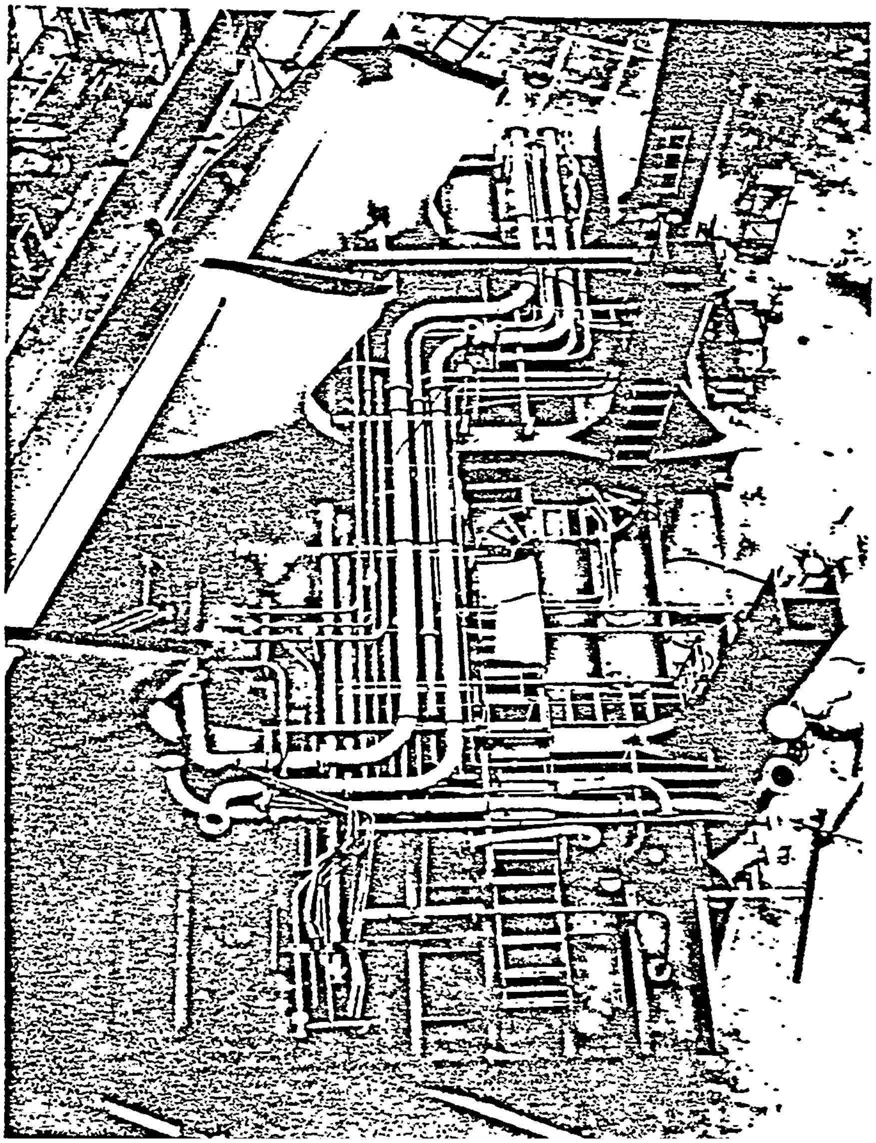


Figure I-6: On-Unit Outfitting on Engine Flat Unit

As.a consequence of preoutfitting on-board outfitting includes., and ideally should be limited to, the connection of modules and/or preoutfitted units, final painting, and tests and trials. However it necessarily includes some installation of outfit components in a hull at erection site or outfitting pier, which cannot be productively incorporated on-module or on-unit outfitting. Figure I-7 illustrates schematic relationship between on-module, on-unit, and on-board outfitting.

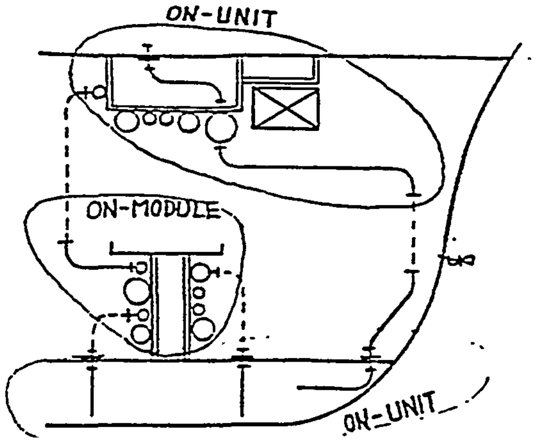


Figure I-7: Schematic relationship between on-module, on-unit, and on-board outfitting.
Dotted lines indicate pipes fitted on-board.

Preoutfitting among zone-outfitting has significantly contributed to the productivity gains. Figure I-8 summarizes the objective and benefits, ie. minimize low-efficiency on-board work and "maximize high efficiency shop work in order to reduce the overall time required to build a ship.

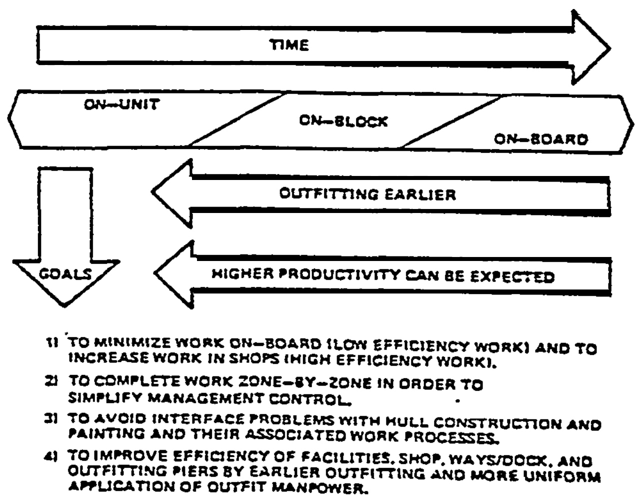


Figure I-8: Summary of Zone Outfitting Goals.

I-3 Palletization

One of indispensable systems for effective zone-outfitting is a concept of pallet. Literally a pallet is a container in which materials are to be contained and to be transported to work site for installation, figure I-9 illustrates a pallet used most commonly and pallets getting ready to be shipped with pipes in them.

Figure I-9: Pallet used in IHI AIOI Shipyard.

On the other hand the word "pallet" also refers to a unit of materials identified by zone, and to a unit of-work specified by zone. It is a conceptual approach that allows information from design, material and production to integrate so that the various functions can have a common understanding of ship building management and/or control.

Following is the summurization of the above.

1. To handle materials conveniently (for easier stowing and transportation)

2. To control material by groups from design to warehousing through purchasing

3. To manage production regarding a pallet as a unit of job.

The report, written by Mr. Yukinawa, has described in detail about palletization recommending applicable style of palletization effectively related to the existing "Work Order System" of LSCO.

I-4 Composite Drawing

Another indispensable element for effective-zone-outfitting is "composite drawing."

The steps developing the design is as follows:

A. Schematic piping diagram — Functional design — Scantling design

↓ ↓ ↓

B. System arrangement (piping, ducting, wiring, and etc.) — Machinery Arrangement — Fabrication plan (for components)

↘ ↓ ↙

C. Composite drawings

Step A is a segment of functional design without specification of position. Step B specifies the rough position or dimention for the actual system, machinery or some components. Step C, composite drawing, specifies position, with an interrelationship of all materials and hull construction. A composite drawing covers an area including single or several sub-zones, in other words pallets, and accordingly all work accompanied with all materials in that area. If the composite drawing cannot include all materials and systems in that area palletizing (i.e. zone-outfitting) may be incomplete.

The report, written by Mr. Mochida, has described in detail about composite drawing with precious know-how in development of LSCO F-32 composite drawing.

II. Preoutfitting Productivity

Table II-1 shows productivity comparison between preoutfitting and on-board outfitting taking the case of engine room outfitting of F-32 built in IHI.

TABLE II-1: Productivity comparison table (Engine Room Outfitting)

(Sno. 2581 1st F-32 Built at Aioi Shipyard IHI)

Categories		Parametric ※ Weight (T)	Manhour (H)	Efficiency (H/T
On-Module	Main floor modules	46.1	980	21.3
	Modules with cooler flat	6.2	190	30.6
	Other modules	40.0	484	12.1
	Welding	-	230	-
	Crane operation	-	170	-
	Sub-total	92.3	2054	21.6
On-Unit	Inner bottom units	4.3	215	50.0
	L.E.F. & U.E.F. Units	12.1	698	57.7
	Main Deck Units	16.7	782	46.8
	in Casing	16.9	979	57.9
	Side Shell Units & Other Units	17.5	525	30.0
	Welding	-	710	-
	Sub-total	67.5	3909	57.9
	Preoutfitting Total	159.8	5963	37.3
On-Board	Piping	18.7	3078	164.6
	Steel Fitting	21.5	2240	104.2
	Others	6.9	1430	207.2
	Welding	-	980	-
	Sub-total	47.1	7728	164.1
	Grand Total	206.9	13691	66.2

※ Short ton: Weight of material such as pipes, valves, foundations, ventilation ducts, and so on, which are considered to have linear relation to manhour spent to install them.

The above table manifests the superiority of preoutfitting over on-board outfitting, i.e. on-module outfitting has 1/7 of on-board outfitting H/T, on-unit outfitting has 1/3, and totally preoutfitting has 1/4. Further 159.8 tons (77%) of total outfitting weight in engine room, 206.9 tons, is preoutfitted.

Figure II-1 illustrates efficiency interrelationship between preoutfitting, on-board outfitting, and total. Each efficiency changes depending on preoutfitting ratio. The on-board efficiency increases (goes down in the graph) untill preoutfitting ratio reaches 60%, thereafter reduces (goes up in the graph) rapidly. The preoutfitting efficiency shows tendency relatively flat. However, the total efficiency steadily increases (goes down in the graph) as far as 90% of preoutfitting ratio. The total efficiency incre (goes down in the graph) particular in the range from 0% to 50% of preoutfitting ratio. It suggest that preoutfitting will prove its superiority even at the initial stage of its application.

The above is one of the main reasons why preoutfitting is highl recommended to LSCO. Further, if preoutfitting were not to be appli a vast sum of manhours would be expected. That is to say, "the more preoutfitting, the more

Table II-2 shows how pre-outfitting raises completion deg of outfitting as of launching, in other words, how preoutiitting contributes to the shortening (building period..

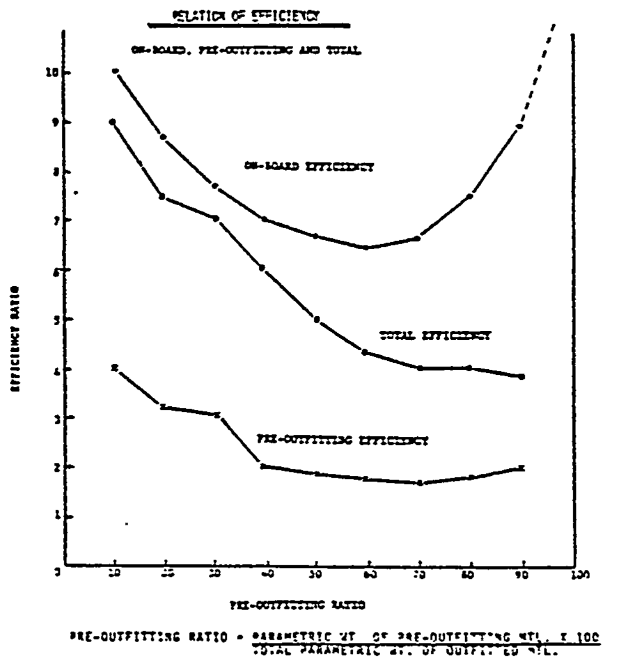


Figure II-1 Efficiency Interrelationship

TABLE II-2: Completion degree as of launching

Sno. *2581* Ist F-32 Built at Aioi Shipyard lHI

Section		Total	as of Launching	
Deck Outfitting	Fitting Weight	77.3. I^{T}	384.2^{1}	(49.7%)
	Manhour	14748^{H}	9188^{H}	(62.3%)
Accommodation Outfitting	Fitting Weight	241.2^{T}	155.6^{T}	(64.5%)
	Manhour	13850^{H}	6828^{H}	(49.3%)
Engine Outfitting	Fitting Weight	206.9^{T}	152.5^{T}	(73.7%)
	Manhour	18893^{H}	11978^{H}	(63.4%)
Electric Outfitting	Fitting Weight	78.2^{T}	50.4T	(64.5%)
	Manhour	11831^{H}	5607^{H}	(47.4%)
Total	Fitting Weight	1299.4^{1}	742 7^{T}	(57.1%)
	Manhour	59322^{H}	33601^{H}	(56.6%)

Reference 1 attached is an evaluation of preoutfitting in LSCO which is the Module 701 and 702 of Hull 751. The evaluation is mainly done through the view point of manhour spent and saved. The module 701 and 702 assembly is considered to have resulted in 3,500 hours sating consequently.

111. On-module Outfitting

Hereafter, recommendable style of on-module outfitting in LSCO is discussed refering to that of IHI.

111-1 Production planning for on-module outfitting

Production planning, both for on-module outfitting and for on-unit outfitting, should undoubtedly be of higher productivity, improved safety, and better quality oriented. For the above, the following two points shoul always be of under consciousness of men in charge as a base line of the planning.

1. To try to fit as much material as possible at preoutfitting stage, either on-module or on-unit.
   (To minimize on-board work)

2. To try to make preoutfitting itself most effective.
   (The more preoutfitting ratio increase, the more it becomes important)

III-4 Module assembling procedure

Generally a module consists of following materials:

1. Machinery
2. Machinery foundations
3. Tanks
4. Pipes, supports, valves, strainers, and etc.
5. Walkways (including handrails)
6. Ladders
7. Electric devices
8. Electric cable, cable hanger and tray
9. Parts of steel construction such as stanchions, web frames and etc.
10. Miscellaneous fittings such as thermometers, gauges.,
11. Painting

On-module outfitting requires various kinds of material to be assembled together, in other words most crafts to be involved, and has to be worked out in relatively short time. It is out of the question that the above requires good coordination between crafts to avoid trouble caused by interferences between crafts, or time loss caused by clumsy work succession from one craft to another. Therefore work procedure has to be studied and established before work start.

The typical and basic procedure is illustrated in figure III-12. Reference 3 is pictures, taken in IHI, illustrating module assembling procedu

In reference 4, the role of prefabricated supports both for pipes and for floor plates, is of remarkable. They are arranged on the slab in early stages of the assembling and work as:

1. Pipe positioning
2. Pipe supporting (literally)
3. Floor plate positioning
4. Floor plate supporting (literally)

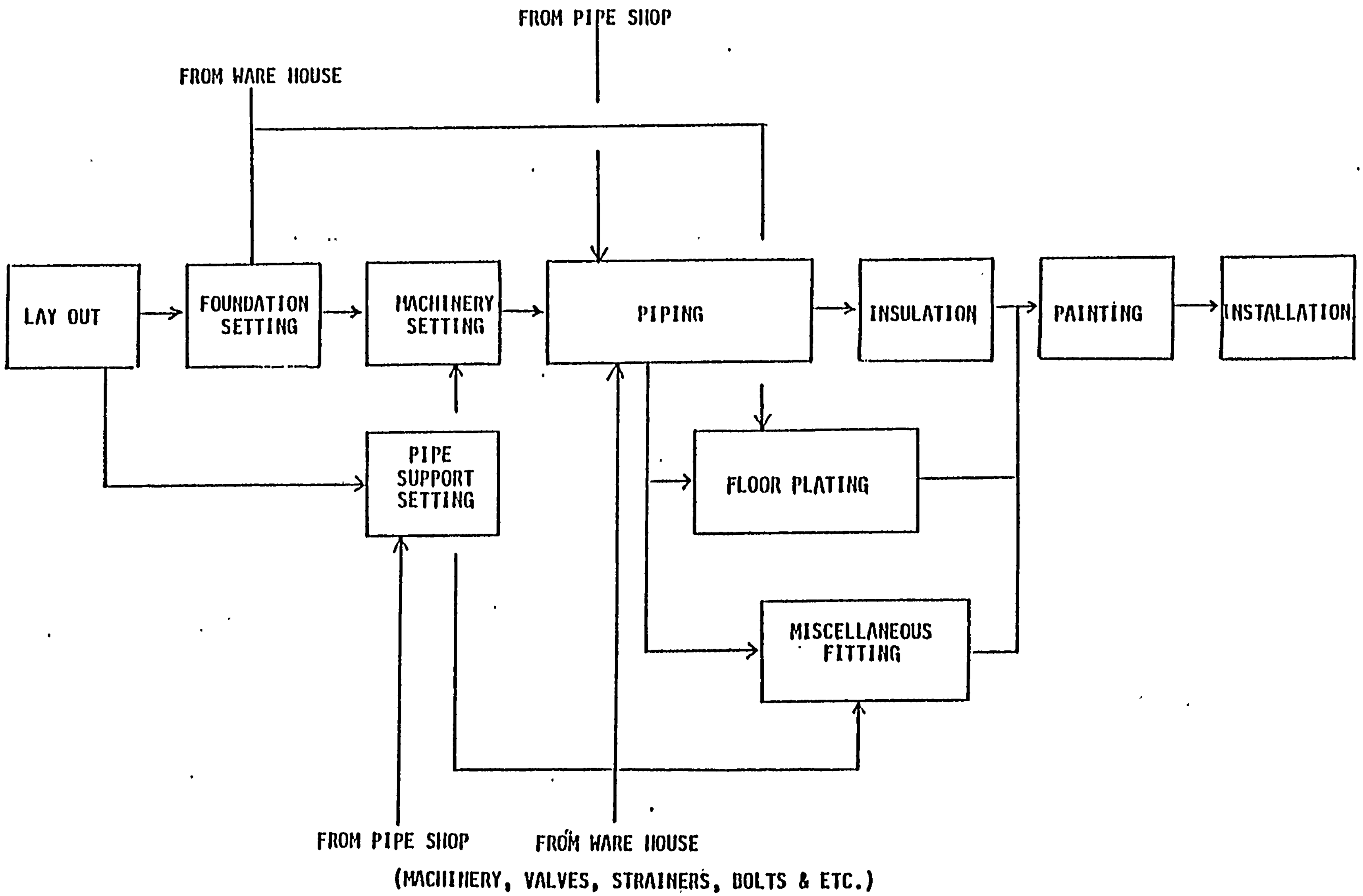


Figure III-12: On-module outfitting procedure

The positioning roles of the above allows to simplify assembling procedure and to save many manhours. In part of reference 5 & 6, the practical planning of positioning support is described.

Though the basic procedure is much the same for most modules, the study and establishment of detail procedure must be done for respective module based on working drawing. It is a big partof productive production planning as mentioned in chapter III-1. Reference 7 is an example of the detail procedure for the module 701 and 702.

III-5 On-module scheduling

Reference 8 is some examples of schedules of module assembly in IHI. It consists of the following:

1. On-module long term schedule

2. On-module monthly schedule

3. Slab usage plan

4. Pallet deliverly schedule

Figure III-13 illustrates scheduling procedure of the above among total scheduling flow of IHI, and which is also recommendable to LSCO.

As modute assembly slab is., or must be, well equipped, 100% utilization of the slab has to be considered in scheduling. Therefore if the total number of module were not enough for 100% utilization *of* the slab, some other works, such as on-unit outfitting or even final assembling of steel, have to be considered to be taken on.

III-6 Module assembly facility

Hypothetically, in this chapter, how facility and equipments of module assembly area should be as a part of the "Gate System" is discussed.

Module assembly area must be satisfied following conditions:

Location

1. Convenience for smooth flow of material.
   -Not too far away from pipe shop, fabrication shop and warehouse-

2. Convenience for installation of assembled modules.
   -Within the reach of dock side crane, if possible-

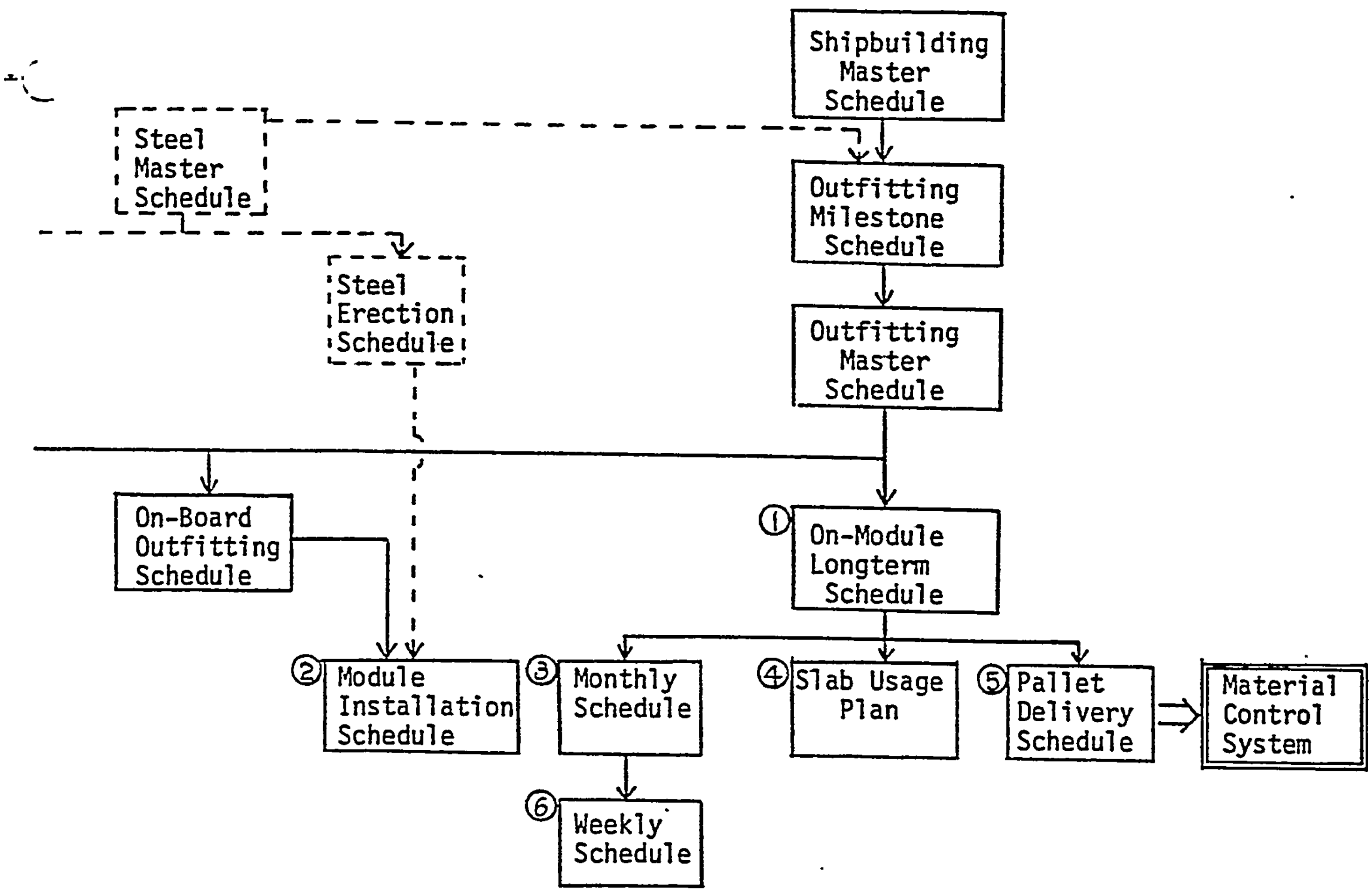


Figure III-12: On-module scheduling procedure among total scheduling flow of IHI.

①, ②, ③, ④, and ⑤ are prepared by staff level.
⑥ is prepared by foreman or assistant foreman level.

(Equipment)

1. Firm and flat slab with enough area to cover whole module assembling planned.
   -In addition to the above some area for material preparation is needed-

2. Crane(s) exclusively used for internal transportation of material and for assembling.

3. General utilities such as electric welding machines, gas and power air supplier.

4. Building with removable roof, if possible.

(a) Location and material flow

Figure III-13 illustrates recommendable location of the module assembly area and material flow. Although the south end of the gate 21, which is assigned for steel component assembling in the gate system, is utilized for the module assembling at this time, the recommended location has more convenience for material flow. Advantages are as follows:

1) Easier transportation and communication with pipe shop newly planned.

2) Closer to the warehouse..

However, the rails of gantry crane which is presently - servicing the gates 21, 25, and 17 must be extended up to the north end of gate 22 for the transportation of assembled modules.

(b) Assembly slab

Figure 111-14 illustrates typical construction of the module assembly slab. It will provide enough strength and workability.

The necessary slab area is estimated as follows:

1) Anticipate major types of ships built in the future.
   Assumed as:
   1.5 bulkers per year
   2.0 jack-ups per year

2) Expect possible modules for the construction of the above types of ships. Table III-2 shows the results.

3) Schedule slab usage based on 1). Figure III-15.

4) Draw slab usage plan of the most crowded period of 3). Figure III-16.

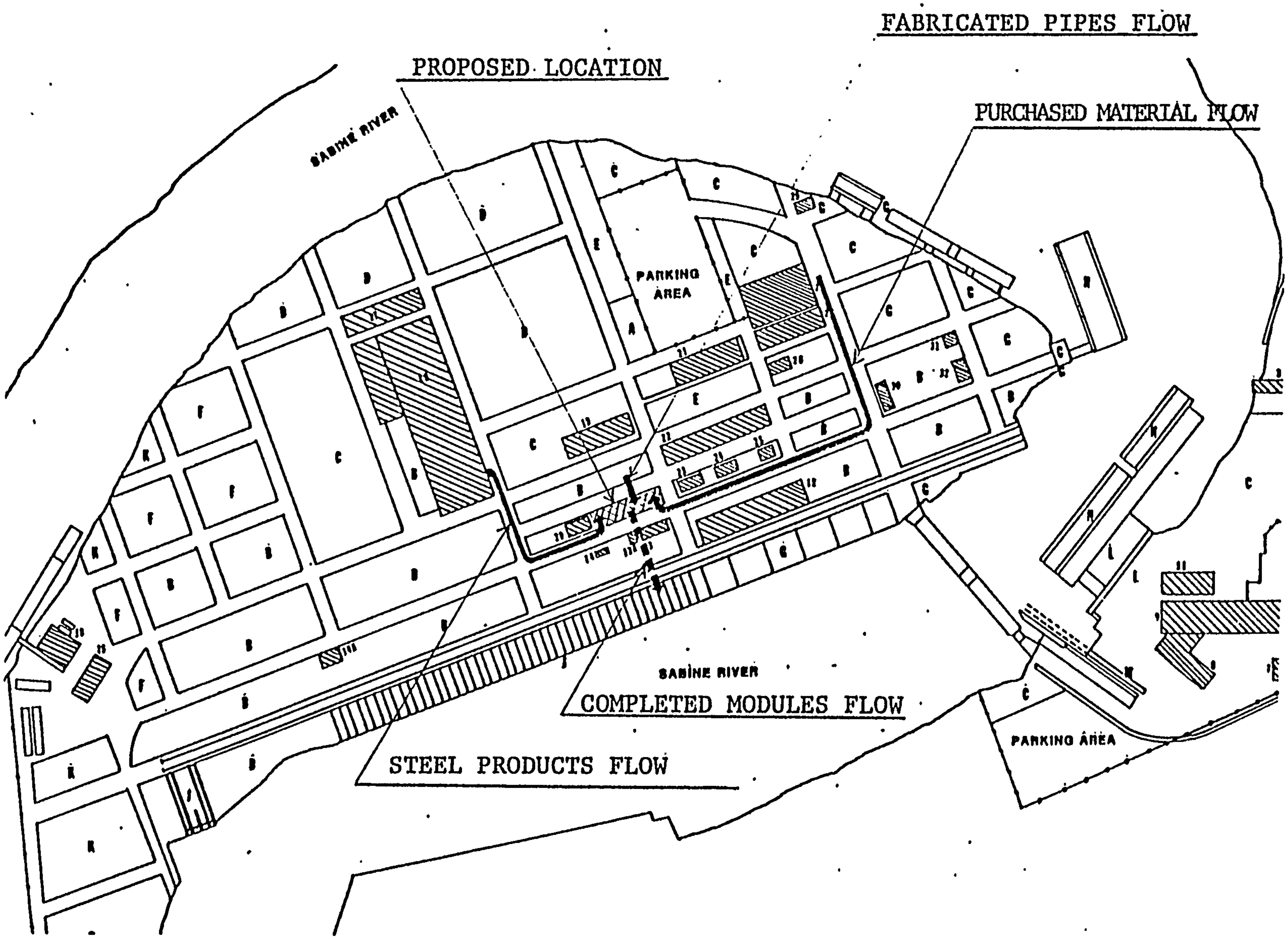


FIGURE III - 13

PROPOSED LOCATION OF THE MODULE ASSEMBLY AREA AND MATERIAL FLOW

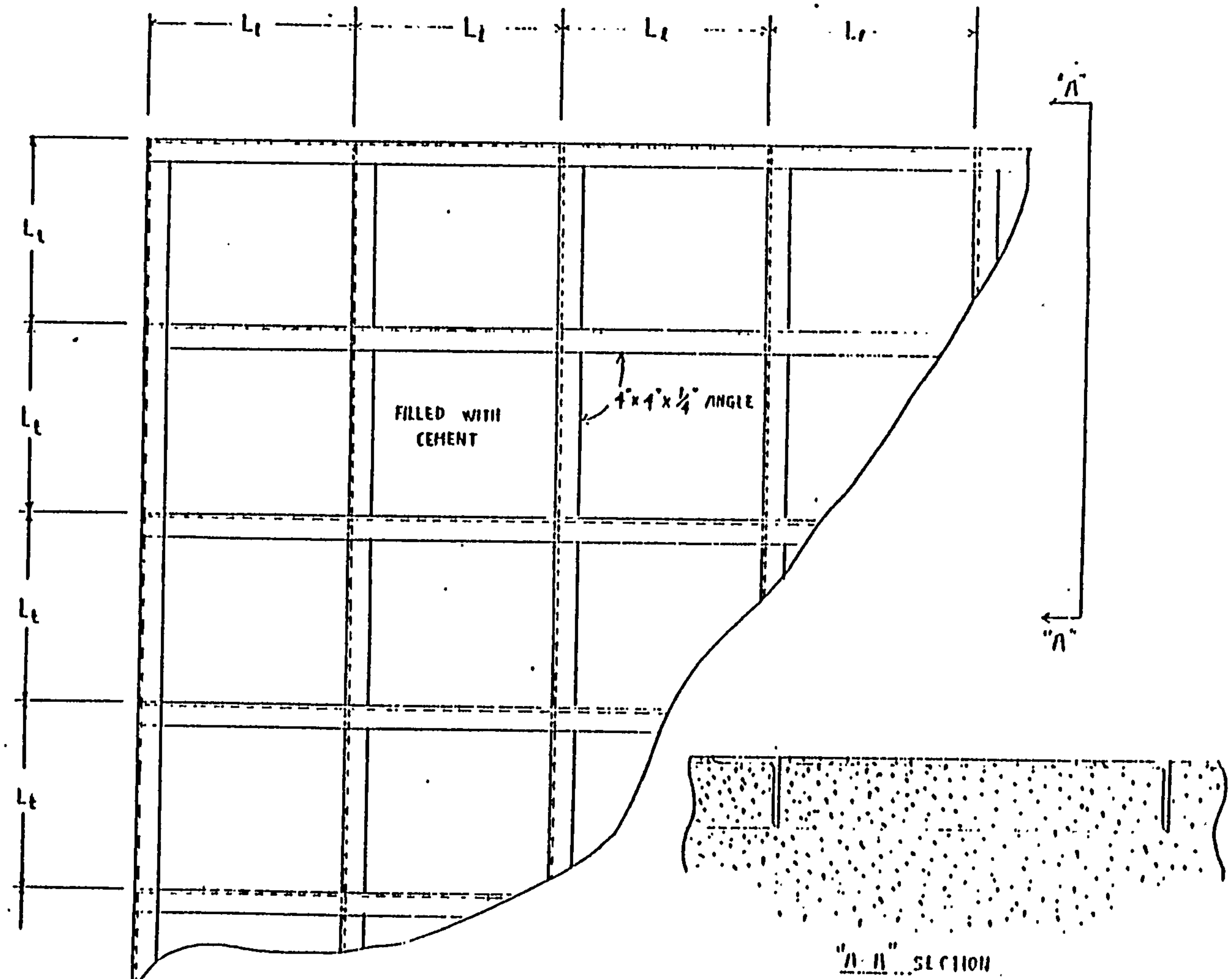


Figure III-14: Module assembly slab construction

Lt: to be equivalent to the most frequent transverce frame space of ships (2'7½" for example)

Le: To be equivalent to the most frequent longitudinal frame space of ships.

Vessel	Name of Module	Size	Necessary Area
Bulker	Ballast, & G.S. pump module (701 & 702)	15' X 50'	750 sq ft
	Starboard Main L.O. Pump Module (703)	10' X 12'	120 sq ft
	L.O. Purifier Module (704)	10' X 10'	100 sq ft
	Port Main L.O. Pump Module (706)	10' X 12'	120 sq ft
	Air Comp. Module (707)	8' X 10'	80 sq ft
	Starboard L.O. Cooler Module (709)	5' X 22'	110 sq ft
	Cascade Tank Module (710)	8' X 10'	80 sq ft
	Port L.O. Cooler Module (713)	5' X 22'	110 sq ft
	F.O. Tank Module (714)	20' X 20'	400 sq ft
	F.O. Booster Pump Module (715)	8' X 12'	96 sq ft
	R/G L.O. Settling Tank Module (717)	7' X 13'	91 sq ft
	D.O. Tank Module (718)	8' X 16'	128 sq ft
	L.O. Tank Module (719)	18' X 18'	324 sq ft
Jack-Up Rig	Generator Room Modules	37' X 50'	1850 sq ft
	Mud Pump Room Modules	42' X 50'	2100 sq ft

Table III-2: Expected modules for construction of the bulker and the Jack-up rig.

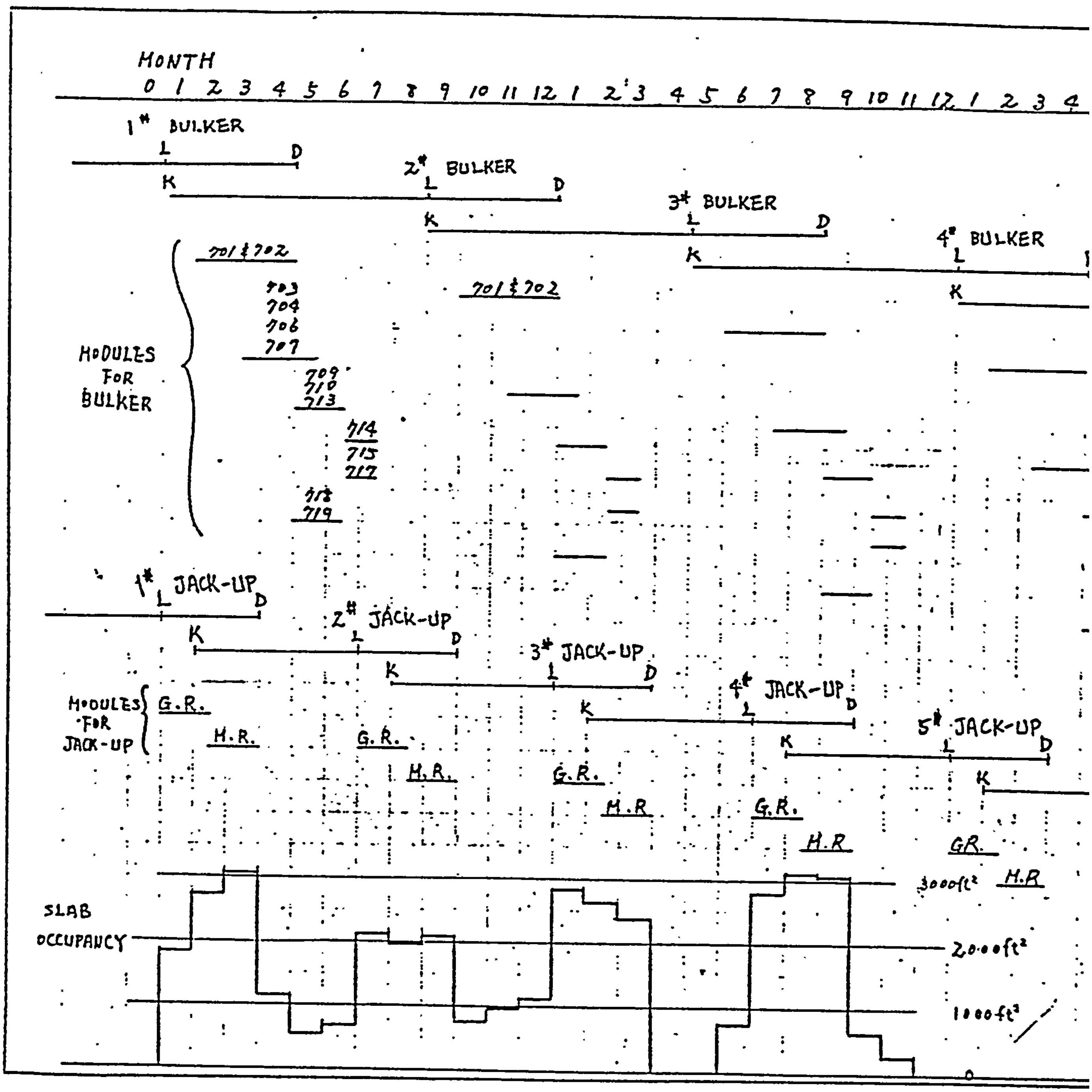


Figure III-15: On-module assembly standard routine schedule

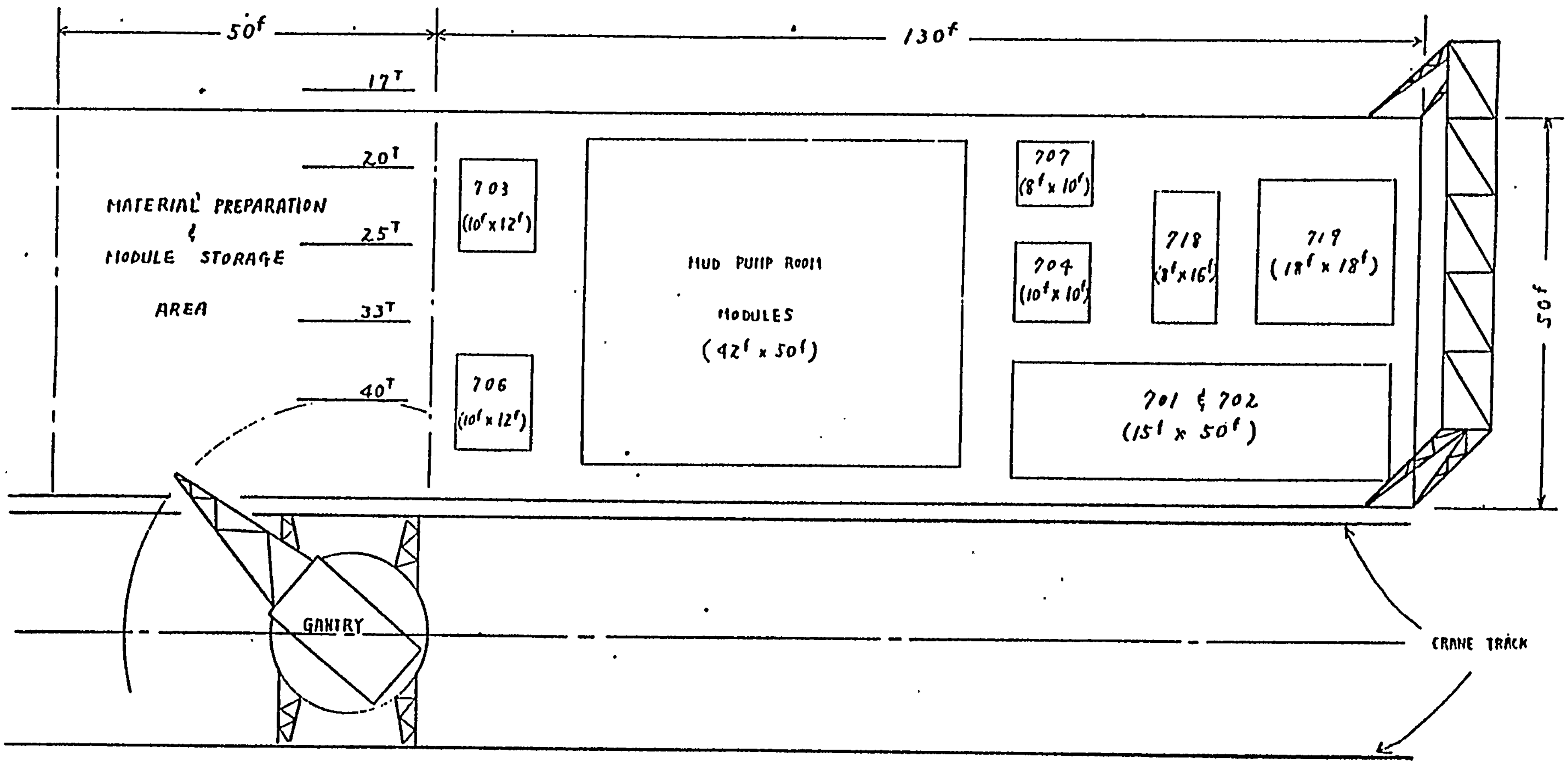


Figure III-16: Slab lay-out and usage plan.

The minimum area necessary is:

50' x 130' = 6500 sq ft

The proposed location in figure III-13 has an area of (50'X 400' = , 20,000 Sq ft). It is wide enough for the module fabrication. Furthermore some additional area (2,500 sq ft) can be utilized for material preparation and/or assembled module storage, and it will not disturb the operation of existing welding facility for legs of jack-uprigs.

IV. On-Unit outfitting

On-unit outfitting, which has much higher applicability in LSCO, is not less effective than on-module outfitting. Table II-1 shows the tendency that on-module outfitting is more predominant rather than on-unit outfitting from the aspect of both application degree (parametric weight distribution) and efficiency. However, it is the tendency only in engine room outfitting. If the comparison is made for entire ship, the tendency will become opposite at least in the aspect of application degree because of following reasons:

1) In all portion but engine room, most outfitting material is positioned very close to steel structure. (Such as innerbottom, hold bulkhead, and so on)

2) In all portion but engine room, to assemble giant module is relatively difficult because most material is decentralized like on main deck for example..

Contrarilyto on-module outfitting, which requires to some degree special facility, on-unit outfitting requires nothing special but a unit on which on-unit outfitting is to be done. It is a point of easy applicability in LSCO.

Furthermore, on-unit outfitting gives solutions for some works to be done under extremely bad circumstances on board, such as inside tanks, beneath decks, on vertical walls, and so on. They can be done very easily on units prior to their erection, before a tank makes closed space, while a unit is situated top side down, and while a wall is laid down. It is out of the question how on-unit outfitting contributes to safety improvement. and quality requirements.

Hereafter, recommendable style of on-unit outfitting in LSCO is discussed refering to that of IHI.

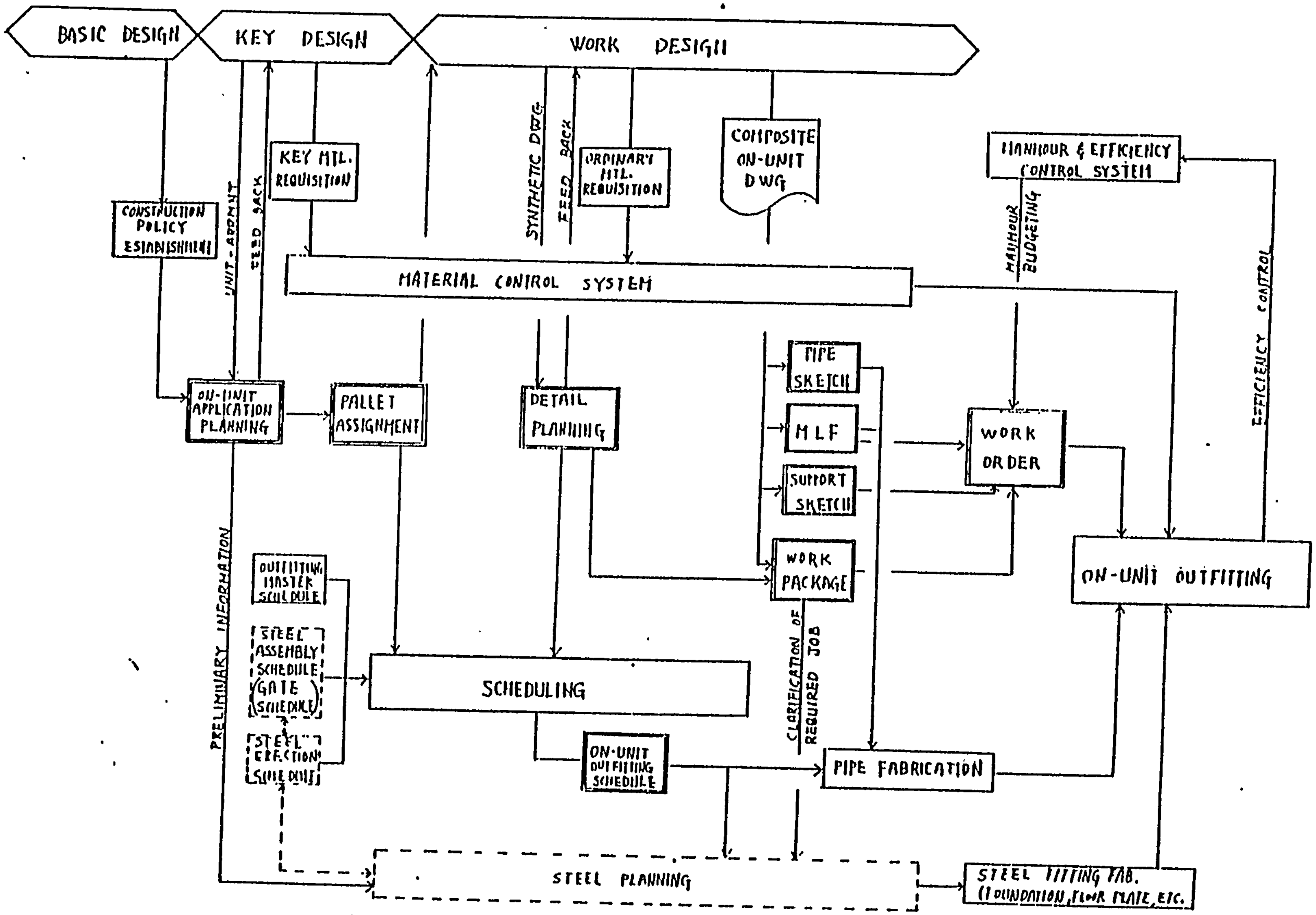
Iv-1 Production planning for on-unit outfi-ttting

The base lines of the production planning for on-unit outfitting are the following as well as those for on-module:

1. To fit as much material as possible at on-unit stage. (To minimize on-board work)

2. To make on-unit outfitting effective.

Figure IV-1 illustrates the recommendable production planning flows of LSCO.



<u>Figure IV-1</u> Proposed production planning flow for on-unit outfitting.

V. Present condition and future improvement

Despite the effore of zone outfitting application to Hull 751, the result is seemingly insufficient. Particularity manhour consumption, which already exceeded the estimation budget as of August, 1980, and adherence to schedule, which resulted frequent correction of scheduled delivery date, apparently reveal the above..

In this chapter, therefore, present condition of outfitting in LSCO is analyzed to clarify problems to be solved, and also the subject of future improvement is identified.

V-1 Present condition

All problems in outfitting field are likely to be summarized in engine room outfitting of Hull 751.

There are two main problems as follows:

1) Insufficient preoutfitting

2) Insufficient zone outfitting on board

1) Insufficient preoutfitting

The amount of material installed at preoutfitting stage was much less than planned and expected. It resulted in the following problems on board.

a) A lot of work under bad circumstances..

Material, planned to be preoutfitted, is generally to be installed in places where it would be hard to be worked at, such as underneath decks, inside tanks, and narrow/closed places. Therefore it would becaome extremely time consuming work, if it had to be worked out on board. It will further affect quality of products and safety of work, particularity engine roomof self propelled vessels which have a severer tendency of the above than corresponding compartment of the other type of vessels such as jack-up rigs, barges, and so on.

b) Burning, disassembling and reassembling of prefabricated pipes.

A lot of prefabricated pipes, which were aimed to be installed at preoutfitting stage, were obliged to be installed at on-board stage. As they were sketched to be suitable to preoutfitting., many of them were burnt, disassembled., re-assembled and mended.

c) Congestion of workers, interference between crafts, and out of sequence works.

Most materials had to be transported on the hull, and many of them had to be positioned (installed) in relatively short period between innerbottom unit erection and main deck unit erection. It caused congestion of material and workers, interference between crafts, and a lot of out of sequence work on board.

2) Insufficient zone outfitting on board

Despite on-board outfitting which was planned to be done sub-zone by sub-zone, the piping which is a key to engine room outfitting was mostly performed system by system. It resulted in the following:

a) Inappropreiateness of composite drawing.

Composite drawing is not for system-by-system outfitting. Therefore it is time consuming to read, to understand, and to identify one system among all other systems drawn on one drawing.

b) Inappropriate palleting.

All prefabricated pipes were grouped and contained into pallets, and transported on the hull sub-zone by sub-zone. Therefore system-by-system outfitting required all pallets to be transported at once, and pipes of one system to be installed had to be pulled *out* of several pallets one by one.

c) Unnecessary movement of workers.

As every system runs in every nook and corner, a worker had to move in every nook and corner at every system if he works system by system..

d) Difficulty of progress monitoring.

As the progress looks vague, it is very hard to grasp the completion degree as a total. In other words, anywhere or any sub-zone would not be completed untill all systems have been completed.

e) Out of sequence works.

System-by-system outfitting sometimes ignores geographical conditions, as indicated in figure V-1.

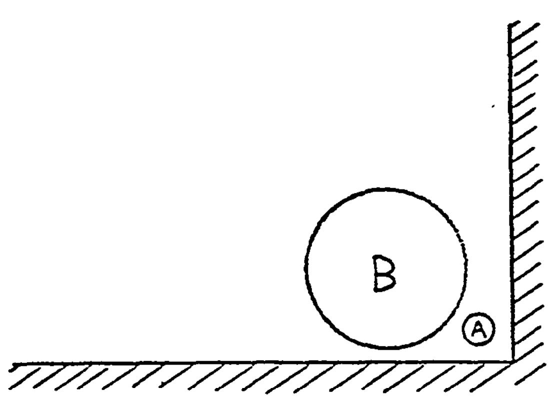


Figure V-1: Conditions sometimes exi where one piping system (A) must be installed before another system (B) In the case of system-by- system outfitting, a fit for system (B) may be un that system (A) should b installed before system (

V-2 Main subjects for future improvement

As a result of present condition analysis, it is out of question that enforcement of zone outfitting, which consists of preoutfitting and on-board subzone outfitting, is the subject to be struggled with for future improvement here in LSCO.

In this section, therefore, vital points of the above enforcement are discussed and proposed with emphasis on production planning and control activity.

1) Enforcement of preoutfitting

The most effective solution to prevent problems taking place on board of Hull 751 at this time is to eliminate on-board work as much as possible, in other words, to enforce preoutfitting as much as possible. Production planning has the key of the above. The following are vital points for substantial production planning, and they should be implemented step-by-step. Figure V-2 and V-3, which are identical to figure III-1 and IV-I, shows the planning flow.

a) Establishment of construction policy.

Settle goals of preoutfitting degree, which are to be reflected on all activity from Engineering through Production.

b) Preoutfitting application .planning.

This orients a guide line of productive construction at which work designing aims. In other words, the success of preoutfitting is dependent on this planning.

Major planning items are as follows;

* which portions are to be preoutfitted
* how they are preoutfitted
* how key drawings are to be ammended

c) Detail planning.

This is the activity aiming at more productive designing by incorporating practical ideas of the production side, and thereby increasing preliminary knowledge of the production side, which allows Production Control to make productive work instructions.

Major Planning arming items done by respective unit of preoutfitting are as follows:

* what material is to be preoutfitted.
* how detail the procedure is..
* what the key points are from the view points of productivity.
* how work drawings are to be amended.

d) Subsidiary materials

Indispensable materials for successful1 preoutfitting are as follows:

* Pipe sketches (for prefabrication).
* Positioning support sketches.
* **MLF**

Preoutfitting with higher productivity than on-board outfitting can not be realized without the above.

e) Work packages and work orders

A work package, which is a total work instruction,should go with a work order in order to be able to reflect matters at the-working site, which are planned previously.

2) <u>Enforcement of subzone outfitting</u>

After preoutfitting enforcement, subzone outfitting on board must be enforced. For subzone outfitting, the scheduling plays the most important role after all. In other words, the scheduling is a starting point of subzone outfitting and the "HEART" of the production planning. Figure V-3 shows planning flow for on-board subzone outfitting.

a) Scheduling

The following are required for subzone scheduling:

* Two kinds of schedules orienting subzone outfitting are necessary.

  1. Comprehensive schedule involving all crafts.
  2. Craft by craft detail schedule.

* An element of comprehensive schedule should be tied up with a pallet or a unit of work defined by a work order.

* Craft by craft detail schedule should be a break-clown of comprehensive schedule.

b) Work order

Work order is required to have the following items used for subzone outfitting:

* To be tied up with elements of the schedule.

* Planned start date and planned finish date must be exactly based on the schedule.

* MLF must go with work order.

* Detail schedules must go with work order as the occasion demands in order to clarify work sequences.

The above preoutfitting and subzone outfitting is the subject which should be mandatory first priority to be implemented because of its very immediate effect on productivity. Furthermore, it will also develop consistently substantial production planning activity.

In addition to the above, on the other hand, the following should be developed as a long-range program in order to up grade production planning and control activities furthermore.

3) Manhour control

a) Proper budgeting

* Introduction of control parameter (Parametric weight)

* Introduction of process standard

b) Manhour monitoring

* Introduction of appropriate monitoring curve. (Manhour "S" curve and Efficiency curve)

* Quick and proper response for something unusual in curves.

Piping craft (Department 9) is likely to be the most potential department to be started on for the above subjects (2) and (3).

IHI MARINE TECHNOLOGY, INC.

2123-2,2-6-2

Ref. No. HP-081

PRACTICAL APPROACH

for

MOLD LOFTING SYSTEM

and

MARKING/CUTTING SYSTEM

without

BIG CHANGE OF PRESENT SITUATION

in

LSCO

REFERENCE : IDEAL APPROACH FOR MOLD LOFTING SYSTEM
IN LSCO
Ref. No. HP-080

APRIL, 1979

PREPARED BY: KOHJI HONDA
IH1 MAHNE TECHNOLOGY, INC.

At the present time, "machine down" of N/C burning often comes about in the shipyard.

Additionally, the fabrication at Zones 2 and 3 in the first bulker will begin in the very near future.

In this condition for a while, it is necessary to take into consideration the making and cutting methods of hull structures with modification of the present mold lofting method.

For the time being, the urgent themes regarding Zones 2 and 3 of the first bulker should be studied as follows:

(1) Hull pieces which are to be operated by the N/C burning machine should be burned by other subcontractors (one if possible), until the recovery of N/C burning machines.

Otherwise, new N/C burning machines should be installed. Now, IHI understands that LSCo has begun to study about the above matter.

(2) Flat plates, such as main deck plates, bottom plates, inner bottom plates, etc., are to be shifted as much as possible from the N/C machine to the flame planner.

Therefore, the work load of N/C machines will be decreased.

(3) The making of such templates of internal hull pieces at Zones 2 and 3 as web-flames, brackets, etc., should be changed from woody templates to other material templates as follows:

- Using film-mat-template
- Using paper piece drawing (size list)
- Others

For mold loft section, making use of these templates will save more time than at the present.

The deep study should be started by both parties of LSCo and IHI in the near future.

As a result of a rough investigation, this report was made.

Possibilities for application of a large N/C drafter-machine and others shall be described in another report, "Ideal Approach for Mold Lofting System in LSCo."

Even if the N/C burning machine is broken, the template can be made on the floor manually,at the present, by using the method addressed in the above-mentioned report.

But this method is not always recommendable for LSCo in the future because of physical mold lofting demerits, which are shown in the "Ideal Approach for Mold Lofting System in LSCo" report.

Ref. No. HP-080

IDEAL APPROACH
for
MOLD LOFTING SYSTEM
in
LSCO.

Attachment: IHI-PRECISION OPTICAL PROJECTION (TEN-TIMES)

Reference:

Task 2.o---ENGIEERING AND DESIGN

Sub-Task 2.1---COMPUTER-AIDED DESIGN SYSTEM

prepared by: M. HATAKE
IHI Marine Technology, Inc.

Task 2.0---ENGIEERING AND DESIGN

Sub-Task 2.2---NUMERICAL CONTROL STEEL FABRICATION

prepared by: M. HATAKE
lHI Marine Technology, Inc.

APRIL, 1979

Prepared by: KOHJ1 HONDA Ø
IHI Marine Technology, Inc.

"Machine down" of N/C burning equipment is a very serious matter for LSCO, particularly for mold loft section, because mold loft section has to manually make templates referring to N/C data registered in the system. But it is difficult to produce the relevant templates of Zones 2 and 3 at this time.

The mold lofting method against "machine down" of N/C.burning equipment should be taken into consideration in the system.

I. MOLD LOFTING SYSTEM

When the N/C machine is broken down, other templates are to be made from N/C data in order to cut hull pieces. But it is difficult to make it.

In order to solve the above difficulties, two kinds of mold lofting systems are to be considered to make templates in this shipyard.

One is a physical mold lofting system; the other is a scaled mold lofting system.

A. Physical Mold Lofting System

In this shipyard, the bulker's flame lines on the mold loft floor are already prepared to make bending templates.

When the N/C machine is broken down, it seems that physical mold lofting system would make it easy to make the full-sized templates of hull pieces. But it would bring about the following problems:

1. Many skilled mold loft men are needed to make full-sized templates.

2. It will take a long time to make woody templates.

3. Making templates at the same place will interrupt their working activity.

On the other hand, the computer system (SPADES) has been utilized to fabricate almost all hull pieces in LSCO.

This computerized system should increasingly be utilized in the future. Therefore, other methods should be established as soon as possible to make many kinds of templates without any difficulties due to the above mentioned problems. In other words, physical mold lofting system is not recommended to LSCo for future use.

This report would advise LSCo to apply the scaled mold lofting system as soon as possible.

II. SCALED MOLD LOFTING SYSTEM

As described before, the scaled mold loft system should be established as soon as possible in LSCo. Generally, the scaled mold lofting system needs scaled body plans and a large N/C drafter machine.

A. In this shipyard, it generally seems difficult to have scaled body plans until an installation of a large N/C drafter machine. However, it is an important matter on how to get the scaled body plans for LSCo. But it seems possible to get the body plans as follows:

(a) The scaled body plans can be done on film-mats by CALI's N/C drafter machine.

(b) Seams and longitudinals will be included in these body plans, together with each frame line and butt line.

This possibility of the above matter will be studied more deeply by LSCo.

After getting the scaled body plans, you can make full-sized templates as follows:

(a) Internal structure sections will be drawn on the body plans by hand by mold loft.

(b) After that, copies of the above films will be delivered to Engineering and mold loft people.

(c) Development of hull pieces shall be done on the above scaled body plans.

(d) Measuring dimension of hull'pieces on these plans will be transferred by hand to full-sized templates, piece drawings (size list), and other necessary information data for production activities.

However, if (d) is the case, a more indepth study should be initiated as follows:

(1) How to measure dimensions of hull pieces
(2) How to describe much information on the template
(3) Etc.

B. The expansion of the computerized ’system applied in LSCO will require a large N/C drafter machine *as* reported before by Mr. Hatake.

This large N/C drafter machine will perform the following activities.

(a) The scaled body plans will be drawn easily

(b) Outputs from SPADES will be drawn into scaled drawings for hull pieces.

After that, these scaled drawings will be checked by mold loft men for their relationship with the scaled body plan.

This checking method is very useful in decreasing error of templates and to keep *a* high accuracy.

In *case* the N/C machine is down, there are two alternate methods of making full-sized templates as follows:

1. Partially Full-Sized Drawing Method

In order to directly make full-sized templates by the N/C drafter machine, drawings will be divided into two or more, as shown in the figure below.

In proceeding with this method, the suitable programs which can divide a one-piece drawing into several pieces of a drawing must be prepared. Thus, re-generated drawings must be of proper size to accommodate the table of the said drafter machine.

2. Optical Enlarging Method (Ref. attached)

   To enlarge a scaled drawing to a full-sized template will be developed by an optical projector.

   If this projector is installed, full-sized templates are easily made by mold loft men from scaled-drawing-film using the drafter machine.

   An optical projector is useful to make the bending templates from the scaled body plans also.

   The making of bending templates will proceed using this equipment without any interference from mold lofting activities.

Our opinion expressed above is just for your reference.

III. CONCLUSION

As we have mentioned above, the best method of replacing activities of the N/C burning machine down will be the following method:

(1) To prepare scaled body plan of film-mat.
(2) To take necessary copies of the above body plan in order to develop every piece on those

(3) To develop full scale templates from scaled piece drawings.

In addition, if a large N/C drafting machine can be provided, "SPADES" System shall be applied to your production more efficiently; such as, preparation of bending template, checking piece drawings, obtaining more information for accuracy control, etc.

We shall appreciate your understanding of the above.

Ref. No. HP-079

IHI - PRECISION OPTICAL PROJECTOR (TEN-TIMES)

IHI - PRECISION OPTICAL PROJECTOR is an optical instrument provided with a function of precise enlargement from a 1/10 scaled film to a full scale image. This is utilized to make a full scale template from a precisely drawn film in 1/10 scale such as templates for bending, template for end cut of stiffeners and others.

In IHI, this machine is installed at Mold Loft and combined use with the NC drafting machine. The specification and function of it and its mechanical principal can be seen in the following description and figure.

SPECIFICATION

1. Effective Dimension To Be Projected

   5.300 M/M length
   3.500 M/M in width

   For the film longer than 5.300 M/M in length sliding the film and projection is repeated to *get a* full length image.

2. Effective Film Dimension

   530 M/M in length
   350 M/M in width

3. Lens

   Fax Ortho Nikkol f=50, F=5.6

4. Light Source

   Relective photo lamp 1OOV, 2KW

5. Electric Source

   3Ø , 200V, 21A

6. Weight

   1,000 kg

7. Other Functions

   *Remote Control Box
   *Film Rolling Equipment

8. Maker

   DAI-NIPPON SCREEN INC.